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ABSTRACT

Five privately owned homes and two university owned homes were examined by architecture students in order to formulate design alternatives to fit the houses with solar collection, storage, and control devices for supplementing domestic space and/or water heating. General principles advanced include why energy conservation and solar retrofitting are important today, and conservation in existing homes as a response to local climatic opportunities, reevaluated assumptions of comfort, general domestic habits, architectural response, and the resulting energy use. Specific alternatives include a description of each home, the owners, their existing comfort requirements, energy needs, and a range of architectural and domestic lifestyle alternatives for energy conservation and solar retrofitting. (Author/MLF)

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ENERGY CONSERVATION
AND
SOLAR RETROFITTING
FOR
EXISTING BUILDINGS IN OREGON:

AN ARCHITECTURAL DESIGN CLASS PROJECT

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EUGENE, OREGON 97403

EA 008 833

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general principles .... Kobe Kemple

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- Solar Collection, Storage and Thermal Control: ....14 Some Parts and Principles

specific alternatives

Some Design Opportunities for:
- The Hills .... Steve Keller, Tom Belvini
- The Bowermans .... John Mele, Ginger Paca
- Kanar Charcoudian .... Gary Edmonds, Quentin Bruhn
- The Higgins .... Ewell Davenport
- The Hunters .... Chris Defferding, Bill Lemons
- A University Owned House at 1685 E 17th .... Art Chinn, Shahab Ghani
- A University Owned House at 1479 Moss Street .... Greg Donald, Brant Nightingale

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- Co-ordinating and Editing .... Kobe Kemple
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- Architecture 380 Design Instructor .... John Reynolds

ENERGY CONSERVATION

IS THE PROCESS OF:

1) EXAMINING ALL ENERGY CONSUMPTION, THE TOOLS, ACTIVITIES, MAN-MADE ENVIRONMENTS AND SUPPORT SYSTEMS THROUGH WHICH WE USE ENERGY.

2) QUESTIONING THE VALIDITY AND EFFICIENCY OF OUR ENERGY USE, AND LONG-TERM EFFECT ON THE HEALTH OF OUR ECONOMY, SOCIETY, AND THE ENVIRONMENT AS A WHOLE.

3) REPLACING WASTEFUL AND ENVIRONMENTALLY DESTRUCTIVE METHODS OF ENERGY USE WITH ACTIVITIES AND LIFESTYLES THAT USE MINIMAL AMOUNTS OF EQUIPMENT, TECHNOLOGY, AND ENERGY TO ACCOMPLISH FUNDAMENTAL TASKS OF HUMAN MAINTENANCE.

SOLAR RETROFITTING

IS THE PROCESS OF "FITTING" AN EXISTING BUILDING WITH SOLAR COLLECTION ,STORAGE, AND CONTROL DEVICES TO ASSIST IN SPACE AND/OR WATER HEATING.

PREFACE AND OBJECTIVES

THIS DOCUMENT IS THE RESULT OF WORK DONE IN A DESIGN STUDIO IN THE DEPARTMENT OF ARCHITECTURE AT THE UNIVERSITY OF OREGON, SPRING OF 1975.

WE ARE DEALING WITH THE PROBLEMS OF A HIGHLY CONSUMPTIVE SOCIETY DEPENDENT UPON NONRENEWABLE ENERGY RESOURCES. THESE SOCIAL PATTERNS ARE RESULTING IN THE NEED FOR ENERGY CONSERVATION, RENEWABLE SOURCES OF ENERGY, AND IN PARTICULAR, SUPPORT SYSTEMS THAT WILL SUPPLEMENT DOMESTIC SPACE AND WATER HEATING BY RETROFITTING EXISTING BUILDINGS WITH SOLAR COLLECTION AND STORAGE SYSTEMS.

AS WE GATHERED INFORMATION AND BEGAN TO WORK TOWARD DESIGN ALTERNATIVES WITH SEVERAL PEOPLE AND THEIR HOMES, WE FOUND THE SUBJECT MATTER INCREASINGLY SIGNIFICANT TO A BROAD RANGE OF PEOPLE. FOR THAT REASON WE HAVE PRESENTED THIS WORK IN A FORM WHICH IS UNDERSTANDABLE AND USEABLE BY MANY PEOPLE.

WE HAVE LEARNED A GREAT DEAL FROM OUR WORK AND HAVE APPRECIATED SHARING IDEAS, NEEDS, AND TALENTS WITH HOME OWNERS AND OTHERS WHO ARE ALREADY USING SOLAR ENERGY FOR THEIR HEATING NEEDS. IT IS OUR HOPE THAT THIS DOCUMENT WILL CONTINUE THIS EXCHANGE WITH A GREATER NUMBER OF PEOPLE HAVING SIMILAR INTERESTS, QUESTIONS AND DESIRES TOWARD MORE SOPHISTICATED AND BALANCED ENERGY USE IN HOMES ACROSS THE FACE OF THE EARTH.

IN ORDER TO MAKE THIS INFORMATION USEFUL FOR AMERICANS IN THEIR HOMES, WE HAVE ORGANIZED OUR WORK IN THE FOLLOWING WAY:

GENERAL PRINCIPLES:

1) A BRIEF STATEMENT OF WHY ENERGY CONSERVATION AND SOLAR RETROFITTING ARE IMPORTANT TODAY.

2) BASIC PRINCIPLES OF CONSERVATION IN EXISTING HOMES AS A RESPONSE TO LOCAL CLIMATIC OPPORTUNITIES, RE-EVALUATED ASSUMPTIONS OF COMFORT, GENERAL DOMESTIC HABITS, ARCHITECTURAL RESPONSE, AND THE RESULTING ENERGY USE.

3) SOME PRINCIPLES OF SOLAR COLLECTION, STORAGE, AND THERMAL CONTROL AS ONE ALTERNATIVE SUPPLEMENT TO PRESENT DOMESTIC SPACE AND WATER HEATING.

SPECIFIC ALTERNATIVES:

4) A DESCRIPTION BY EACH DESIGN TEAM OF A HOME, THE OWNERS, THEIR EXISTING COMFORT REQUIREMENTS, ENERGY NEEDS AND A RANGE OF ARCHITECTURAL AND DOMESTIC LIFESTYLE ALTERNATIVES FOR ENERGY CONSERVATION AND SOLAR RETROFITTING.

introduction

IN THE LAST SEVENTY-FIVE YEARS WITH INCREASED ENERGY AVAILABLE, MORE SPECIALIZED OCCUPATIONS, AND GREATER TECHNICAL COMPLICATION IN MOST AREAS OF OUR LIVES, WE HAVE COME TO TAKE MANY THINGS FOR GRANTED.

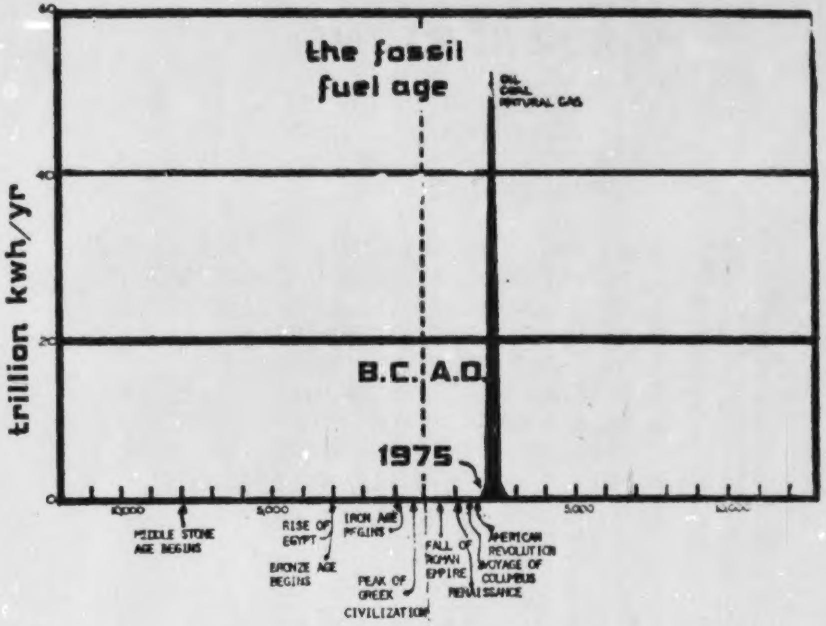
IN 1970 THERE WERE 68.6 MILLION HOUSING "UNITS" IN THE UNITED STATES, 9.2 MILLION ON THE WEST COAST AND 0.74 MILLION IN OREGON. ACCORDING TO THE U.S. CENSUS OF HOUSING, THE FUELS USED FOR SPACE AND WATER HEATING WERE UTILITY GAS, FUEL OIL, COAL, WOOD AND ELECTRICITY (BOTH FUEL AND HYDRO GENERATED).

EXTENSIVE ENERGY AND RESOURCE ACCOUNTING HAS RECENTLY SHOWN MOST OF THE FUELS WE USE TO BE CLEARLY LIMITED IN SUPPLY.

EVEN IF EVERY NEW HOUSE BUILT AFTER 1975 WERE ENTIRELY DEPENDENT UPON CLEAN, RENEWABLE SOURCES OF ENERGY, THE VAST MAJORITY OF CONSUMPTION WOULD STILL BE TAKING PLACE IN EXISTING HOMES WHOSE DEPENDENCE IS UPON QUICKLY DIMINISHING RESOURCES AT INCREASING PRICES.

OUR CHOICES ARE NOT LIMITED TO A STANDARD SET OF INDUSTRIAL SOLUTIONS.

EACH DWELLING, LIKE EACH INDIVIDUAL, HAS ITS OWN SET OF LOCAL RESOURCES TO DRAW FROM. IT SEEMS CLEAR THAT EVEN SMALL CHANGES TOWARD LOCALIZED ENERGY USE WILL BE WISE INVESTMENTS FOR THE FUTURE.



"THERE ARE PERFECTLY SAFE AND CONVENIENT WAYS OF HANDLING ALL ASPECTS OF OUR LIVES AFFECTED BY ENERGY WITHOUT HAVING TO DEPEND IN ANY WAY ON FOSSIL FUELS OR NUCLEAR POWER. THIS SHOULD BE OBVIOUS, AS THERE HAVE BEEN MANY CULTURES IN OUR WORLD EQUALLY AS REFINDED, LUXURIOUS, SOPHISTICATED AND COMFORTABLE AS OUR OWN--SOME EVEN MORE SO--WITHOUT OUR DEPENDENCE UPON ENERGY. IT IS NOT SO OBVIOUS BECAUSE WE ARE ONLY FAMILIAR WITH FOSSIL FUELS AND NUCLEAR POWER, AND ARE UNFAMILIAR WITH THE DIFFERENT PATTERNS OF BENEFITS AND PROBLEMS ASSOCIATED WITH OTHER WAYS OF DOING THINGS."

FROM "LIVING LIGHTLY"
BY TOM BENDER

DIRECT ENERGY USE BY RESIDENTIAL SECTOR, OREGON 1973

IN TRILLION BTU

	Electricity	Natural Gas	Fuel Oil	O-P Gas	Coal	Total
Space Heat	13.9	24.4	39.7	2.8	.50	81.3
Water Heat	11.0	3.2	.6	.6	.03	15.4
Cooking	3.2	.6	.02	.2		4.0
Clothes Dryer	1.9					1.9
Clothes Washer	.2					.2
Refrigerator	3.4					3.4
Freezer	1.6					1.6
Lighting	3.0					3.0
Air Conditioner	.3					.3
Television	1.6					1.6
Fans, Misc.	1.4					1.4
Dish Washer	.3					.3
Sub-Total	41.8	28.8	40.3	3.6	.53	114.5
Auto Use — Gasoline: Approx. 22.0 Trillion BTU used by tourists						140.1
Total						254.5

WHERE, IN OUR HOMES, WE HAVE DEPENDED ON LARGE SUMS OF ENERGY IN THE FORM OF FOSSIL FUELS TO PRODUCE AND TRANSPORT FOOD, WE CAN RELY UPON LOCALLY GROWN FOOD AND PERSONAL GARDENS. WHERE WE HAVE USED AUTOMOBILES TO COMMUTE MANY MILES TO AND FROM WORK, OUR WORK MIGHT BE WITHIN WALKING DISTANCE OR EVEN IN OUR HOMES. WHERE WE HAVE EXPECTED THE GROSS NATIONAL PRODUCT TO INCREASE EVERY YEAR IN MEASURE OF OUR WEALTH, WE MIGHT FIND A NO GROWTH, STEADY STATE ECONOMY TO BE AN ATTRIBUTE TO ALL ASPECTS OF OUR HEALTH.

THE IMPLICATIONS OF ANY CHANGE ARE FAR REACHING AND DEEPLY ROOTED INDEED.

ENERGY CONSERVATION AND SOLAR RETROFITTING FOR SPACE AND WATER HEATING IN EXISTING BUILDINGS IS PRIMARILY BASED ON MORE DIRECT AND EFFICIENT USE OF EXISTING LOCAL SOURCES OF ENERGY WITH A HIGH LEVEL OF INTEGRATION WITH NATURAL SYSTEMS AND CONTROL AT LOW TECHNOLOGICAL AND ENERGY EXPENSE.

OUR DOMESTIC HABITS HAVE DEPENDED UPON SEEMINGLY UNLIMITED CENTRALIZED ENERGY, AND AS A RESULT, THE BUILDINGS WE USE ARE BECOMING INCREASINGLY COSTLY TO HEAT AND MAINTAIN.

IF WE REVERSE THESE TRENDS WE WILL FIND THAT CONSERVATION AND SAVINGS WILL FOLLOW. FOR EXAMPLE, WE CAN:

1) CLEARLY UNDERSTAND AND ANTICIPATE LOCAL CLIMATIC FLUCTUATIONS.

2) ARRIVE AT A CAREFUL EVALUATION OF PERSON COMFORT RESPONDING TO CLIMATIC CHANGES.

3) MODIFY OUR EXISTING BUILDINGS TO TAKE ADVANTAGE OF CLIMATIC OPPORTUNITIES, PROVIDING SHELTER FROM CLIMATIC EXTREMES WITH THE USE OF MINIMAL ENERGY AND EQUIPMENT.

IT IS NO LONGER A QUESTION OF A HEALTHY ENVIRONMENT OR A HEALTHY ECONOMY; IT MUST BE BOTH AT ALL SCALES OF ENDEAVOR!

climate and human comfort

WITH THE ADVENT OF THE ELECTRIC THERMOSTAT AND CENTRAL HEATING SYSTEMS FED BY "CHEAP" ENERGY, THE HOUSE AS A SENSITIVE FILTER OF CLIMATE HAS LARGELY BEEN FORGOTTEN.

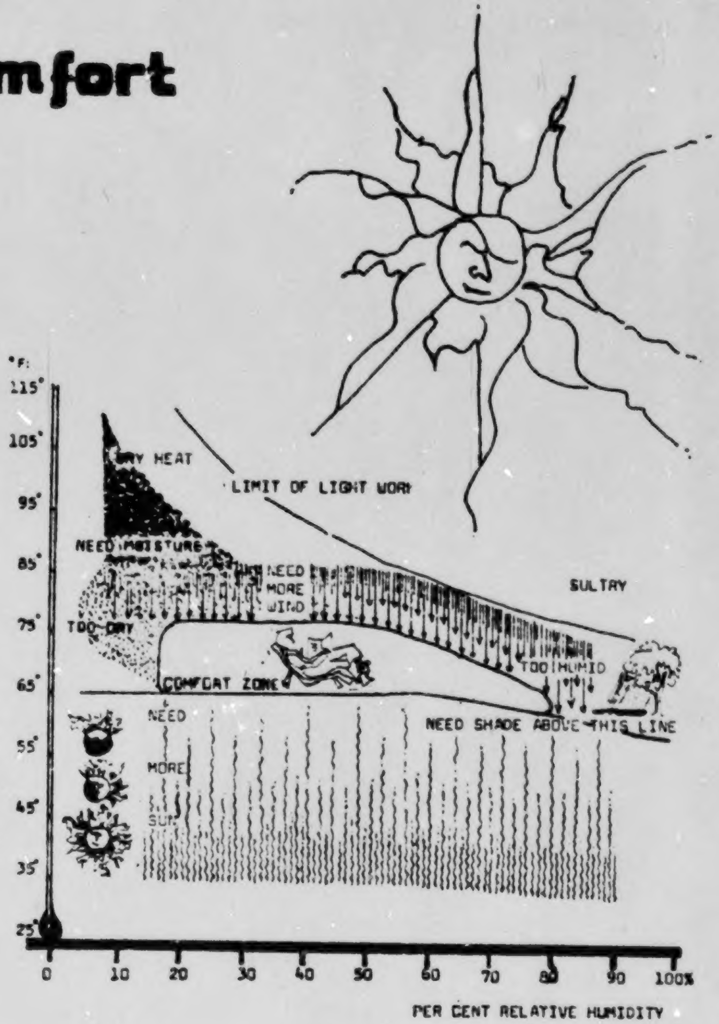
HOME AS A FLEXIBLE MEDIATOR BETWEEN COMFORT AND THE CHANGEABLE CLIMATE IS A SIMPLE, AND VERY IMPORTANT CONCEPT TO BUILD UPON.

PHYSICAL COMFORT INITIALLY DEPENDS UPON AIR TEMPERATURE, THE AMOUNT OF MOISTURE IN THE AIR (RELATIVE HUMIDITY), THE AMOUNT OF WIND AND RADIANT HEAT COMING DIRECTLY TO OUR BODIES.

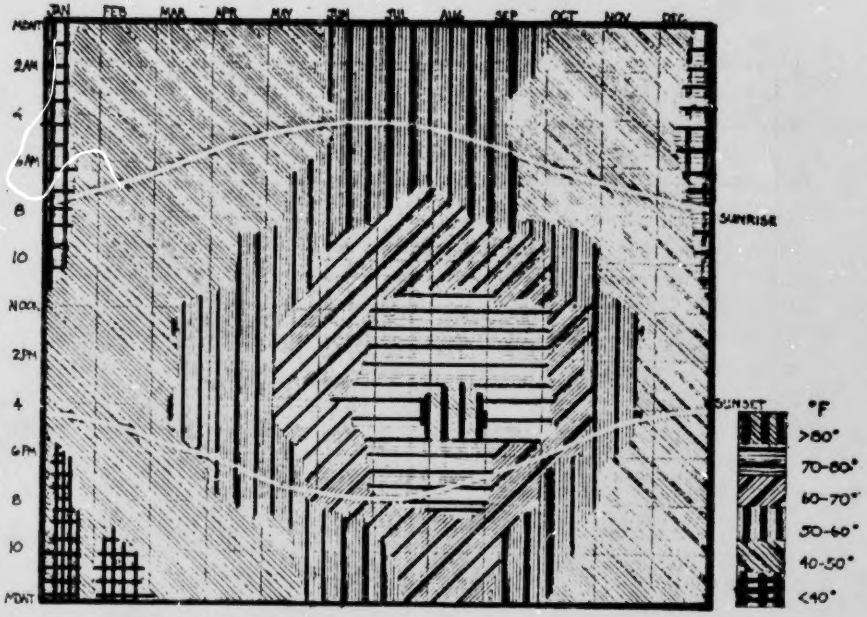
THIS CHART EXPLAINS THE CLIMATIC CONDITIONS IN WHICH MOST OREGONIANS FEEL COMFORTABLE; IN THE SHADE, AT REST, WITH NO WIND, AND WEARING NORMAL LIGHT CLOTHING.

WHEN THE TEMPERATURE DROPS BENEATH THE "COMFORT ZONE", ADDED RADIANT HEAT, INSULATION, OR BOTH ARE NECESSARY TO MAINTAIN PERSONAL COMFORT. WHEN THE TEMPERATURE EXCEEDS THE COMFORT ZONE, INCREASED WIND IS NECESSARY TO CARRY UNWANTED HEAT AWAY.

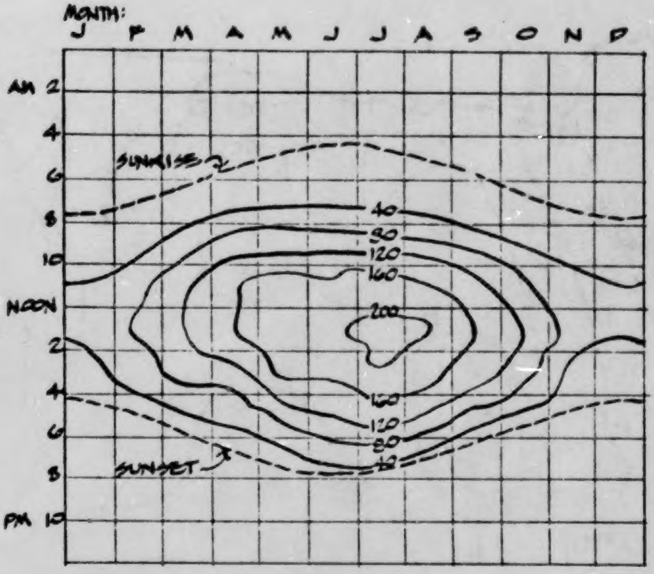
WE USUALLY RESPOND TO THERMAL CHANGE QUITE DIRECTLY BY ADDING LAYERS OF CLOTHING TO RETAIN VALUABLE HEAT, OR BY REMOVING LAYERS, ALLOWING UNWANTED HEAT TO BE CARRIED AWAY.



OUR HOUSES SHOULD BE FLEXIBLE ENOUGH TO RESPOND IN THE SAME WAY WITH MINIMAL USE OF ENERGY AND MECHANICAL EQUIPMENT.



TEMPERATURE for EUGENE



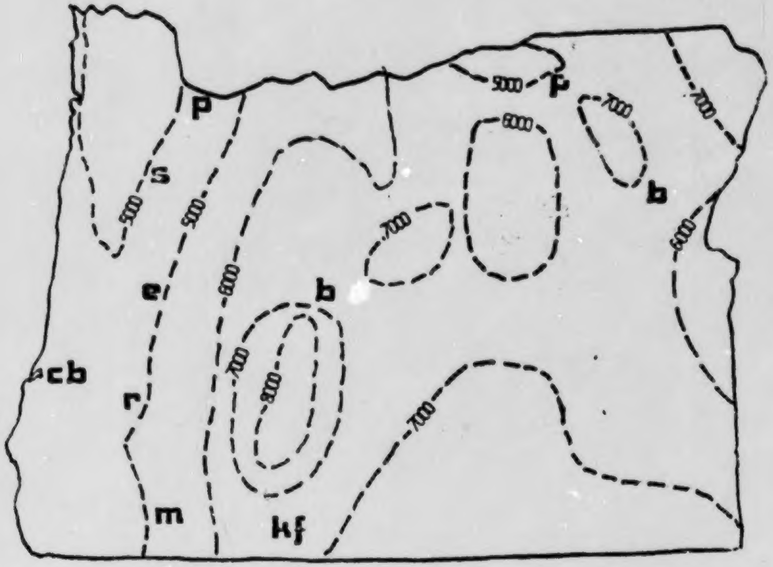
average hourly radiation; btu

ON HORIZONTAL SURFACE AT CORVALLIS, OREGON,
6 YEAR AVERAGE

THESE TIMETABLES CAN HELP US UNDERSTAND CLIMATIC CONDITIONS HOUR BY HOUR THROUGHOUT THE YEAR SO THAT WE CAN FULLY RESPOND TO THE CLIMATE WITH OUR DWELLINGS; OPENING THEM TO OPPORTUNITIES AND SEALING THEM OFF FOR PROTECTION.

USUALLY 8-10 YEARS OF DATA IS NEEDED FOR RELIABLE CHARTS. IN THE CASE OF INCOMING SOLAR RADIATION, INSTRUMENTS HAVE NOT BEEN COLLECTING CONSISTENT INFORMATION THIS LONG. THIS CHART IS FROM ROUGH DATA AND GIVES A GENERAL IDEA OF WHAT A SOLAR INCOME TIMETABLE FOR CORVALLIS, OREGON MIGHT BE LIKE.

climate, comfort and energy use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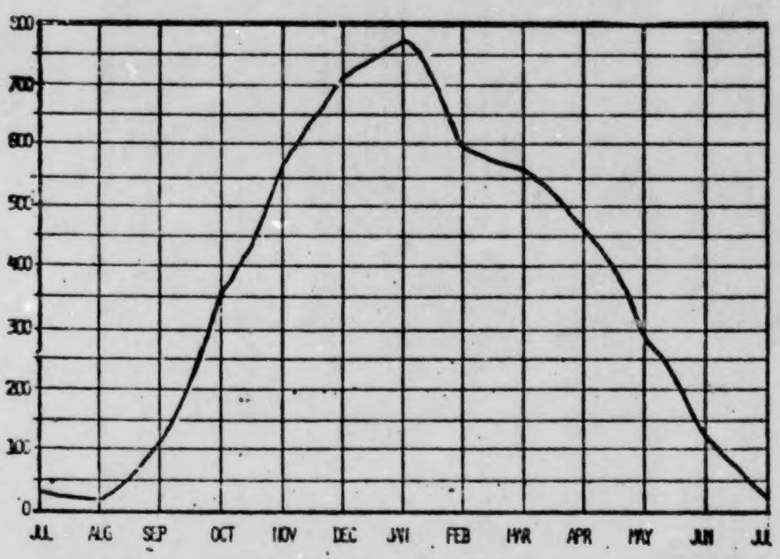
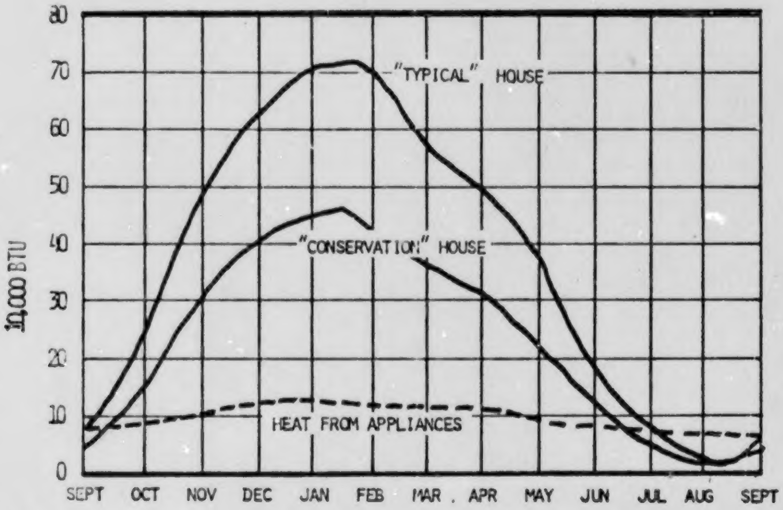
degree days, oregon

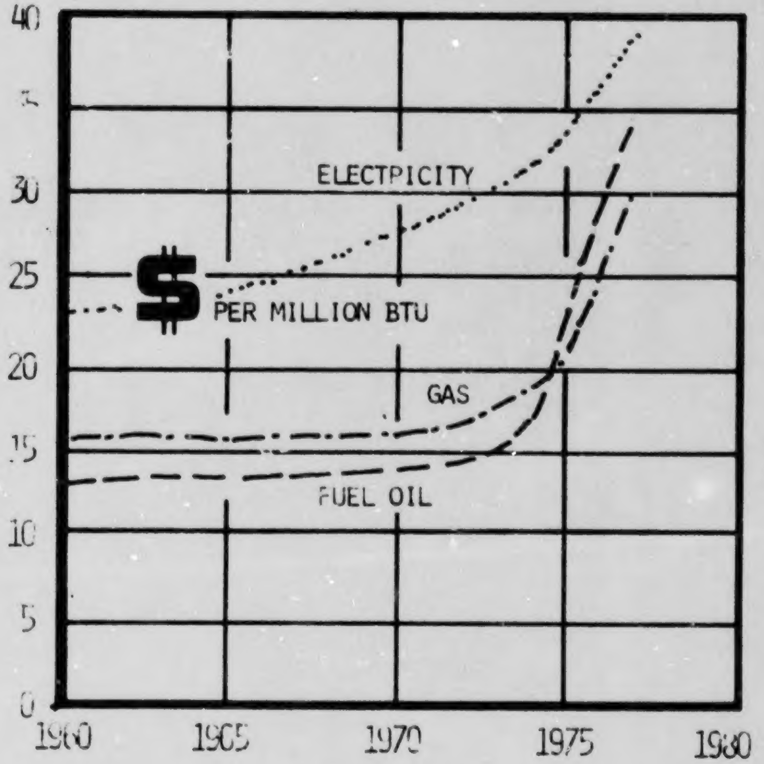


degree days, eugene

IN ANY ONE PERIOD OF TWENTY-FOUR HOURS THE NUMBER OF DEGREE DAYS IS THE DIFFERENCE BETWEEN THE MEAN OUTDOOR TEMPERATURE AND 65 DEGREES. THUS, THE LOWER THE TEMPERATURE, THE MORE DEGREE DAYS. THIS IS COMMONLY USED TO DETERMINE THE TOTAL HEATING NEED FOR A BUILDING THROUGHOUT THE YEAR.



daily space heat needs



ANOTHER WAY TO LOOK AT HUMAN COMFORT
AND THE RESULTING ENERGY DEMAND IS
FROM A PURELY ECONOMIC POINT OF VIEW.

....energy flow through "my" home

THERE ARE MANY COMPLEX WAYS IN WHICH WE USE ENERGY IN OUR HOMES, AND WHEN THAT ENERGY ARRIVES TO US IT IS TRANSFERRED THROUGH MANY DIFFERENT FORMS AND IN THE END, TO HEAT.

WHERE DOES THAT ENERGY ORIGINATE, HOW DO WE USE IT AND, IN THE FORM OF HEAT, HOW DOES IT MOVE IN OUR DWELLINGS?

THE FIRST LAW OF THERMODYNAMICS STATES THAT ENERGY CAN NEITHER BE CREATED NOR DESTROYED.

THE SECOND LAW OF THERMODYNAMICS STATES THAT WHEN A FREE EXCHANGE OF HEAT TAKES PLACE BETWEEN TWO BODIES, THE HEAT IS ALWAYS TRANSFERRED FROM THE WARMER BODY TO THE COLDER ONE.

THESE LAWS TELL US THAT ENERGY IS GENERALLY BEING DISPERSED, THAT OUR MAINTENANCE AND WELL-BEING DEPEND UPON THE RELATIVE CONTROL WE HAVE OVER THE DISPERSAL OF AVAILABLE RESOURCES AS WE USE THEM.

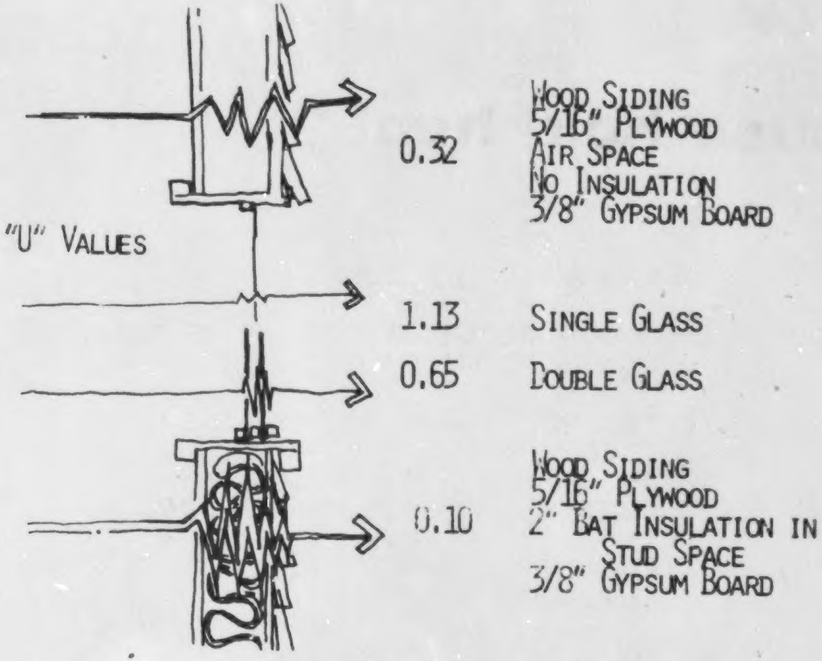
DOMESTIC HOT WATER TANKS USE REFINED, HIGH GRADE ENERGY (ELECTRICITY OR GAS) FOR LOW GRADE HEAT. MANY HOUSEHOLDS KEEP 20-60 GALLONS OF WATER AT 150°F. ALTHOUGH SOME HOUSEHOLD TASKS REQUIRE WATER AT THAT TEMPERATURE, 110°F. IS ADEQUATE FOR MOST PURPOSES.

A FROST FREE REFRIGERATOR USES ABOUT 200 KWH/MONTH. A REGULAR MODEL USES ABOUT 80 KWH/MONTH.

A SURPRISING NUMBER OF HOUSES RELY ALMOST ENTIRELY ON THEIR FURNACE OR ELECTRIC BASEBOARD TO MAINTAIN A LEVEL OF COMFORT IN THE HOUSE. MANY HAVE LITTLE OR NO INSULATION AND SOME HAVE CLEAR SOUTHERN EXPOSURES BUT DO NOT TAKE ADVANTAGE OF THAT AVAILABLE SUN. WITHOUT PROPER CONTROLS, LARGE EXPANSES OF GLASS ALLOW EXCESSIVE HEAT GAIN ON HOT DAYS AND ALLOW VALUABLE HEAT TO ESCAPE ON COLDER DAYS.

A CLOTHES DRYER USES TECHNOLOGY AND MANY PROCESSES OF ENERGY REFINEMENT THAT TURN HIGH GRADE ENERGY (ELECTRICITY) INTO LOW GRADE HEAT.

DRYING CLOTHES OUTSIDE ON A SUNNY DAY IS A SIMPLE OPPORTUNITY TO USE THE CLIMATE AT NO EXPENSE.


"U" VALUES
0.32
WOOD SIDING
5/16" PLYWOOD
AIR SPACE
NO INSULATION
3/8" GYPSUM BOARD
1.13
SINGLE GLASS
0.65
DOUBLE GLASS
0.10
WOOD SIDING
5/16" PLYWOOD
2" BAT INSULATION IN STUD SPACE
3/8" GYPSUM BOARD

HEAT ENERGY TRAVELS THROUGH DIFFERENT MATERIALS AT DIFFERENT RATES. EACH MATERIAL HAS ITS OWN RESISTANCE, ABSORPTANCE, CONDUCTANCE, TRANSMITTANCE, AND EMITTANCE TO DESCRIBE ITS THERMAL PROPERTIES.

MOST OFTEN WE ARE CONCERNED ABOUT THE AMOUNT OF HEAT ENERGY IN BTU'S THAT WILL TRAVEL THROUGH A PARTICULAR MATERIAL, OR LAYER OF MATERIALS, IN A GIVEN PERIOD OF TIME.

A BTU IS THE AMOUNT OF HEAT ENERGY REQUIRED TO RAISE THE TEMPERATURE OF ONE POUND OF WATER ONE DEGREE FAHRENHEIT.

1 BTU = 252 CALORIES
= 778 FOOT POUNDS
= 1055 JOULES
= 0.000293 KWH

THE NUMBER OF BTU'S THAT TRAVEL THROUGH A SPECIFIC MATERIAL PER TIME UNIT IS THE RESISTANCE (R) OF THAT MATERIAL TO HEAT FLOW. WHEN SEVERAL MATERIALS ARE BUILT ON ONE ANOTHER AS IN A WALL, ROOF OR FLOOR, WE USE A COEFFICIENT OF THERMAL TRANSMISSION, OR "U" FACTOR WHICH ACCOUNTS FOR TOTAL THERMAL PROPERTIES OF AIR SPACES, AIR FILMS, AND THE COMBINED BUILT UP LAYERING OF ALL MATERIALS. THE "U" FACTOR IS THE RECIPROCAL OF THE RESISTANCE AND IS EQUAL TO THE BTU LOSS PER SQUARE FOOT PER HOUR FOR EACH DEGREE TEMPERATURE DIFFERENCE BETWEEN THE OUTDOORS AND INDOORS.

$$U = 1/R = BTU/Sq\ Ft/Hr$$

IN GENERAL A MATERIAL WITH A HIGH U VALUE (A LOW R VALUE) WILL LOSE HEAT QUICKLY.

A MATERIAL WITH A LOW U VALUE (HIGH R VALUE) WILL LOSE HEAT MORE SLOWLY.

A "TYPICAL HOUSE" (AT AN OUTDOOR DESIGN TEMPERATURE OF 15°F.) WILL LOSE ABOUT 40 BTU/SQ. FT. OF FLOOR AREA/HR.

A "CONSERVATION HOUSE" WILL LOSE ABOUT 25 BTU/SQ. FT. OF FLOOR AREA/HR.

A SLEEPING PERSON GENERATES ABOUT 280 BTU/HR.

A SEATED PERSON GENERATES ABOUT 400 BTU/HR.

A PERSON DOING HOUSEWORK GENERATES ABOUT 800 BTU/HR.

A 60 WATT LIGHT BULB GENERATES ABOUT 204 BTU/HR.

how well does my house hold heat?

heat loss:

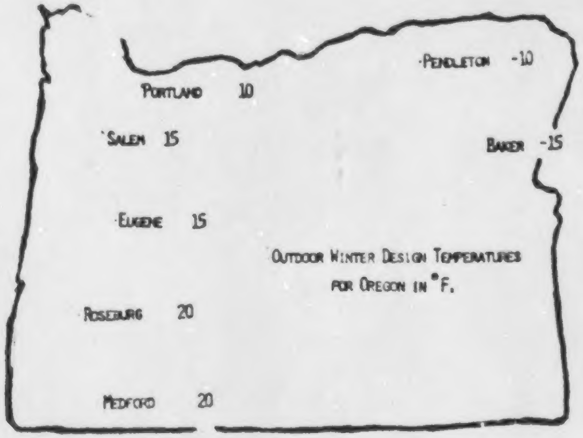
JUST AS HUMANS LOSE HEAT THROUGH THEIR SKIN AND THROUGH THEIR LUNGS, SO DOES A HOUSE.

IN CONSIDERING THE HEAT LOSS OF A BUILDING THROUGH ITS SKIN, WE NEED TO LOOK AT EACH PART, MEASURE THE TOTAL AREA, AND ASSIGN A "U" FACTOR TO EACH SECTION OF ROOF, WALL, FLOOR, AND GLASS. WE MUST ALSO CONSIDER THE DIFFERENCE BETWEEN OUTDOOR AND INDOOR TEMPERATURE (△T) ON A COLD WINTER DAY. THE OUTDOOR WINTER DESIGN TEMPERATURE HAS BEEN ESTIMATED FOR MOST PARTS OF THE COUNTRY. INDOOR TEMPERATURE IS CONSIDERED NORMAL FROM 55-65°F.

FOR EACH PART OF THE HOUSE:

1) MEASURE THE AREA OF THAT PART OF THE SKIN (ROOF, WALL, FLOOR, GLASS).
2) FIND THE "U" VALUE THAT IS CLOSEST TO THE COMPOSITION OF THAT PART. IF THERE ARE DIFFERENT KINDS OF SECTIONS ADD THEM AS SEPARATE PARTS.
3) CHOOSE THE APPROPRIATE WINTER DESIGN TEMPERATURE.
4) MULTIPLY THESE FIGURES FOR EACH SEPARATE PART.
5) AND ADD THE PARTS TOGETHER FOR A TOTAL HEAT LOSS IN BTU'S/HR./SQ. FT.

AS FOLLOWS:


PENDLETON -10
PORTLAND 10
SALEM 15
BAKER -15
EUGENE 15
OUTDOOR WINTER DESIGN TEMPERATURES FOR OREGON IN °F.
ROSEBURG 20
MEDFORD 20

skin loss

ROOF AREA(__SQ. FT.) x ("U" VALUE __) x (△T) = ____ BTU/HR. ROOF

WALL AREA(__SQ. FT.) x ("U" VALUE __) x (△T) = ____ BTU/HR. WALL

FLOOR AREA(__SQ. FT.) x ("U" VALUE __) x (△T) = ____ BTU/HR. FLOOR

GLASS AREA(__SQ. FT.) x ("U" VALUE __) x (△T) = ____ BTU/HR. GLASS

____ = BTU/HR. TOTAL

SKIN LOSS THROUGH ROOFS

"U" VALUE	PITCHED ROOFS
0.53	ASPHALT SHINGLES OR ROLLED ROOFING WOOD SHEATHING ON JOISTS JOISTS EXPOSED INSIDE, NO CEILING NO INSULATION
0.06	ASPHALT SHINGLES OR ROLLED ROOFING WOOD SHEATHING 3 1/2" FLEXIBLE INSULATION GYPSUM BOARD, LATH AND PLASTER
0.21	ASPHALT SHINGLES OR ROLLED ROOFING ONE SHEET REFLECTIVE ALUMINUM ONE AIR SPACE
0.31	ASPHALT SHINGLES OR ROLLED ROOFING WOOD SHEATHING WOOD OR GYPSUM BOARD LATH AND PLASTER
0.49	WOOD SHINGLES WOOD STRIPS ON JOISTS NO CEILING: NO INSULATION
0.06	WOOD SHINGLES WOOD STRIPS ON JOISTS 3 1/2" FLEXIBLE INSULATION GYPSUM BOARD LATH AND PLASTER
0.21	WOOD SHINGLES WOOD STRIPS ON JOISTS ONE SHEET REFLECTIVE ALUMINUM ONE AIR SPACE
0.30	WOOD SHINGLES WOOD STRIPS WOOD OR GYPSUM BOARD LATH AND PLASTER

"U" FACTORS	FLAT ROOFS
0.34	2" WOOD ROOF DECK NO INSULATION NO CEILING
0.25	2" WOOD DECK NO INSULATION 3/8" GYPSUM BOARD
0.06	2" WOOD ROOF DECK 3 5/8" FLEXIBLE INSULATION 3/8" GYPSUM BOARD
0.04	2" WOOD ROOF DECK 2" INSULATION BOARD 3 5/8" FLEXIBLE INSULATION GYPSUM BOARD

SKIN LOSS THROUGH GLASS

"U" VALUES	VERTICAL GLASS
1.13	SINGLE GLASS
0.65	DOUBLE GLASS
	HORIZONTAL GLASS (SKYLIGHT)
1.22	SINGLE GLASS
0.70	DOUBLE GLASS

SKIN LOSS THROUGH ABOVE GRADE FLOORS

"U" VALUES	ABOVE GRADE FLOORS
0.39	NO INSULATION 13/16" HARDWOOD FLOORING
0.09	2" FLEXIBLE INSULATION 13/16" HARDWOOD FLOORING
0.53	3" BARE CONCRETE
0.47	6" BARE CONCRETE

SKIN LOSS THROUGH WALLS

"U" VALUE	
0.32	WOOD SIDING 5/16" PLYWOOD AIR SPACE NO INSULATION 3/8" GYPSUM BOARD
0.10	WOOD SIDING 5/16" PLYWOOD 2" BAT INSULATION IN STUD SPACE 3/8" GYPSUM BOARD
0.09	WOOD SIDING 5/16" PLYWOOD 2" BAT INSULATION IN STUD SPACE REFLECTIVE PAPER ON COLD SIDE 1" AIR SPACE 3/8" GYPSUM BOARD
0.41	STUCCO 5/16" PLYWOOD AIR SPACE, NO INSULATION 3/8" GYPSUM BOARD
0.25	WOOD SHINGLES 5/16" PLYWOOD AIR SPACE NO INSULATION 3/8" GYPSUM BOARD

"U" VALUE	MASONRY WALLS
0.50	8" BRICK NO SPACE NO INTERIOR FINISH
0.20	8" BRICK 1" FURRING SPACE FLEXIBLE INSULATION GYPSUM BOARD
0.36	4" STONE 8" HOLLOW CINDER BLOCK NO INTERIOR FINISH
0.18	4" STONE 8" CINDER BLOCK 1" FURRING SPACE FLEXIBLE INSULATION GYPSUM BOARD

lung loss

TO MEASURE THE LUNG LOSS (OR THE HEAT LOSS DUE TO AIR EXCHANGE AND INFILTRATION) WE NEED TO MEASURE THE TOTAL VOLUME OF THE HOUSE. ASSUME THAT THERE IS ONE COMPLETE AIR EXCHANGE PER HOUR (1/2 A CHANGE IN A TIGHTLY WEATHER STRIPPED HOUSE), USE THE INDOOR AND OUTDOOR DESIGN TEMPERATURE (55-65° F. AND 15°F. FOR EUGENE) AND A CONSTANT (0.018) WHICH IS DERIVED FROM THE SPECIFIC HEAT OF AIR AND THE AVERAGE DENSITY OF AIR PER CUBIC FOOT (0.24 BTU x 0.075 LB./CU. FT. = 0.018)

VOLUME OF THE HOUSE ______ (CU. FT./HR) x (ΔT ___) x (0.018) =

____ BTU/HR. LUNG LOSS

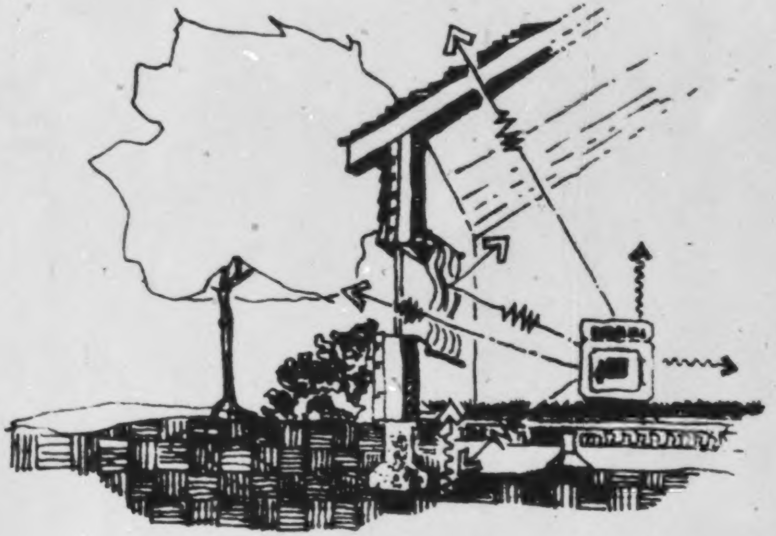
insulation. economics.....

AMERICAN HOMES USE ABOUT ONE-THIRD OF THE ELECTRICITY IN THE NATION AND A GOOD DEAL OF THE FOSSIL FUEL. FOR THIS AMOUNT OF CONSUMPTION THERE IS VERY LITTLE PERSONAL CONTROL OF THAT EXPENDED ENERGY. SINCE MOST OF THE ENERGY USED IN THE HOME ENDS UP AS HEAT, MORE CONTROL AT A PERSONAL LEVEL CAN BE ACHIEVED BY THE USE OF INSULATION OR A DIVERSITY OF HEAT SOURCES.

THE RENTER OF A HOUSE PROBABLY HAS THE LEAST AMOUNT OF CONTROL OVER THE ENERGY FLOWS THROUGH HIS HOME. MAJOR CHANGES WHICH HE SEES AS NECESSARY TO INCREASE THE EFFICIENCY OF HIS HOME WOULD PROBABLY BE REFLECTED IN INCREASED RENTAL COSTS; HENCE HIS PROPERTY REMAINS UNIMPROVED.

THE PURCHASER OF A SPECULATIVELY BUILT HOUSE ONLY HAS AS MUCH CHOICE AS THE CURRENT ECONOMY AND HOUSING MARKET ALLOW. THESE TRENDS ARE LARGELY DETERMINED BY PROFIT MOTIVES AND BUILDING CODES WHICH HAVE MORE TO DO WITH SHORT TERM ECONOMIC GOALS THAN WITH LONG TERM CONSERVATION. ONCE THE INITIAL PURCHASE HAS BEEN MADE, THE OWNER USUALLY HAS VERY LITTLE CAPITAL LEFT WITH WHICH TO IMPROVE AN UNDERINSULATED HOUSE.

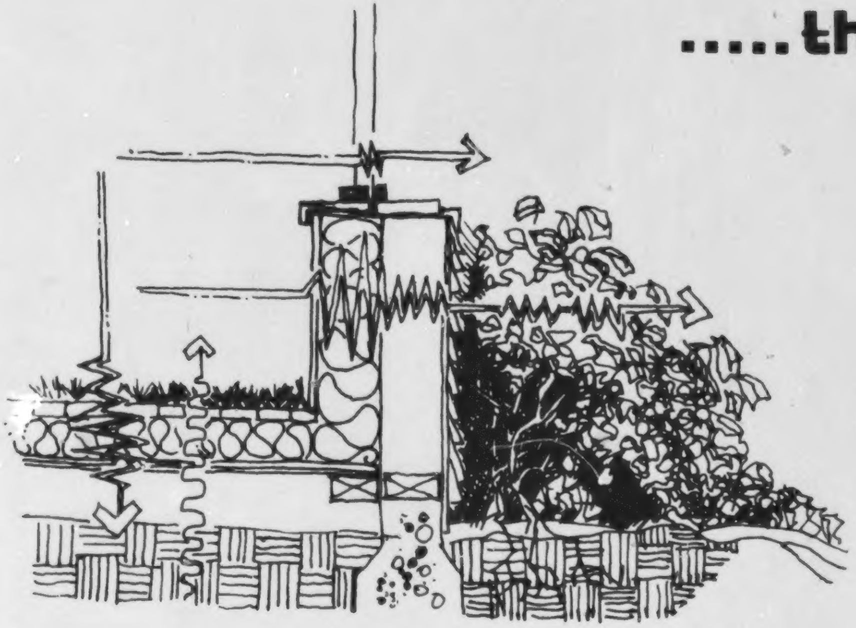
THE BUYER OR BUILDER OF A CUSTOM HOME USUALLY HAS THE MOST CONTROL OVER THE THERMAL QUALITY OF HIS HOUSE. HOWEVER, HE OFTEN LACKS SUCH NECESSARY INFORMATION AS CLIMATIC DATA AND A FULL RANGE OF DESIGN POSSIBILITIES WHICH WOULD ENABLE HIM TO CHOOSE THERMAL CONTROL SYSTEMS MOST APPROPRIATE TO HIS PARTICULAR SITUATION.



ALTHOUGH CODES AND HOUSING STANDARDS ARE INCREASING THEIR DEMAND FOR SUFFICIENT THERMAL INSULATION IN HOUSES THERE IS STILL A NEED FOR PERSONAL RESPONSE IN MANY SMALLER ACTS OF THERMAL CONSERVATION. ADEQUATE INSULATION AND GOOD THERMAL DESIGN DURING CONSTRUCTION IS A LOGICAL SOLUTION. AN EXISTING BUILDING MAY REQUIRE SOME MAJOR REMODELLING TO BRING INSULATION UP TO CONSERVATION LEVELS.

INSULATION AND DOUBLE GLASS IS BECOMING INCREASINGLY ECONOMICAL. THE BETTER THE INSULATION, THE MORE MONEY THAT WILL BE SAVED AS HOME HEATING COSTS CONTINUE TO RISE.

.....thermal control



INSULATION COMES IN A NUMBER OF FORMS: ROLLS OF SPUN GLASS WHICH CAN BE INSTALLED IN EXPOSED WALL AND CEILING CAVITIES, FOAM WHICH CAN BE BLOWN INTO WALLS OR CEILINGS, AND FIBROUS OR PLASTIC MATERIALS OFTEN IN SHEETS WHICH CAN BE APPLIED TO A VARIETY OF EXISTING SURFACES AND WHICH COULD DOUBLE AS A BULLETIN BOARD OR SOMETHING SIMILAR. MOVEABLE INSULATION, BOTH EXTERIOR AND INTERIOR, IS ANOTHER WAY TO CONTROL SOLAR HEAT GAIN AND INTERIOR HEAT LOSS.

IN ADDITION TO INSULATION WHICH COULD REQUIRE MAJOR REMODELLING, THERE ARE MANY MINOR CHANGES WHICH CAN BE PHASED OVER A PERIOD OF TIME WITH LESS CAPITAL INVESTMENT. IF THE MAJOR ELEMENTS OF A HOUSE ARE NOT ADEQUATELY INSULATED, ONE WALL AT A TIME COULD BE DONE AND THE WHOLE HOUSE COMPLETED OVER A PERIOD OF YEARS. A VESTIBULE COULD BE ADDED AT THE MOST ACTIVE ENTRANCE AS A THERMAL AIRLOCK. BOOKSHELVES AND TAPESTRIES CAN BE ARRANGED TO GIVE ADDED INTERIOR INSULATION. INSTEAD OF HEATING THE ENTIRE BUILDING, HEAVY CURTAINS OR MOBILE PARTITIONS IN STRATEGIC LOCATIONS WILL HELP CONFINE THE HEAT WHERE IT IS WANTED.

VEGETATION ALONG EXTERIOR WALLS WILL PROVIDE BOTH WINTER AND SUMMER INSULATION BY CREATING DEAD AIR SPACES AND SHADE. EARTH BERMS (MOUNDS) FORMED AGAINST NORTH WALLS MINIMIZE HEAT LOSS. WOODEN WINDOW FRAMES LOSE HEAT MORE SLOWLY THAN METAL ONES, AND DOUBLE GLASS IS A DEFINITE ENERGY SAVER. ANOTHER CONSIDERATION FOR PROVIDING INSULATION IS TO USE SMALLER WINDOWS WITH CAREFULLY CHOSEN VIEWS.

solar collection systems: parts and principles

MOST OF THE ENERGY WE USE ON THE EARTH IS FROM THE SUN.

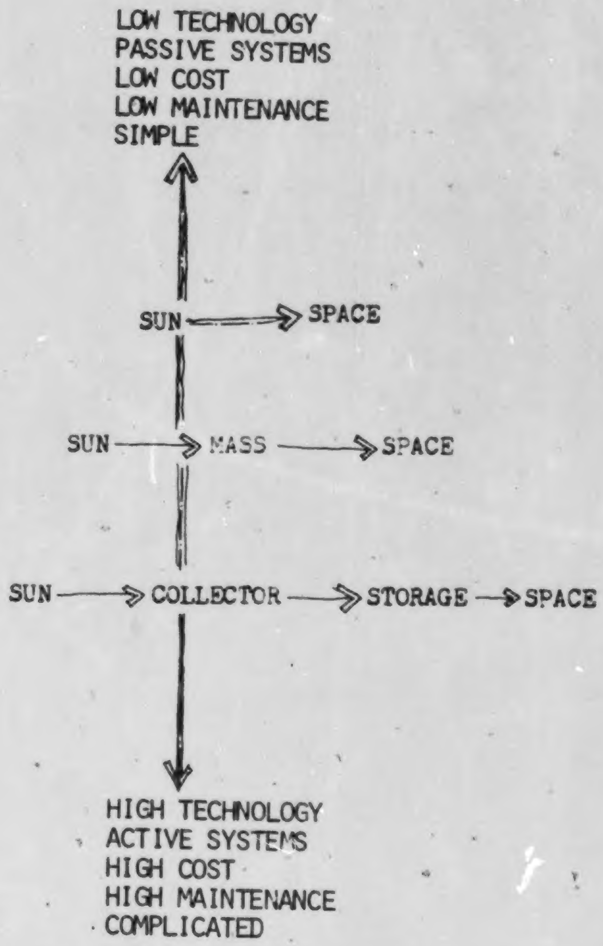
PETROLEUM IS A PRODUCT OF THE SUN, PHOTOSYNTHESIS AND ORGANIC MATTER WHICH HAS BEEN IN THE EARTH UNDER PRESSURE FOR LONG PERIODS OF TIME.

THE SUN EVAPORATES WATER INTO RAIN, FORMING RIVERS WHICH TURN GENERATORS AT DAMS.

THE SUN CAN BE COLLECTED WHEREVER AND WHENEVER IT SHINES. COLLECTION CAN BE SIMPLE WITH NO CAPITAL INVESTMENT AND A FEW CAR PARTS OR IT CAN BE HIGHLY TECHNICAL AND VERY EXPENSIVE.

VERY SIMPLY..THERE IS THE SUN...THERE IS A SCHEME OF COLLECTION...THERE IS A MEANS OF CONTROLING COLLECTED HEAT.

HERE ARE THREE BASIC CONTEXTS IN WHICH THE SUN CAN BE USED FOR SPACE AND/OR WATER HEATING.


LOW TECHNOLOGY
PASSIVE SYSTEMS
LOW COST
LOW MAINTENANCE
SIMPLE
SUN
SPACE
SUN
MASS
SPACE
SUN
COLLECTOR
STORAGE
SPACE
HIGH TECHNOLOGY
ACTIVE SYSTEMS
HIGH COST
HIGH MAINTENANCE
COMPLICATED

SUN SPACE

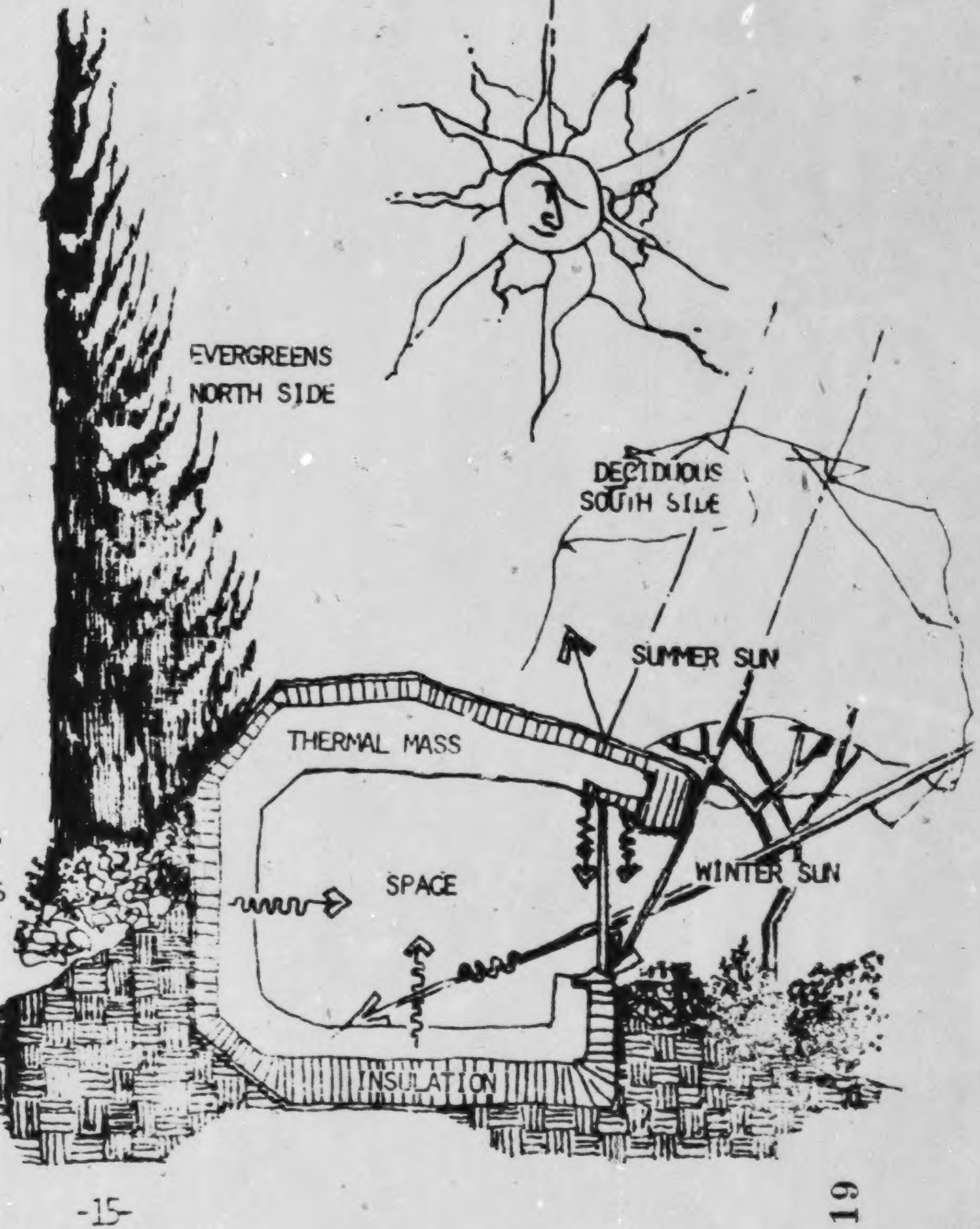
CONVERTING THE SUN'S ENERGY DIRECTLY TO SPACE HEAT IS THE SIMPLEST AND MOST DIRECT MEANS OF SOLAR COLLECTION. IT IS ALSO SOPHISTICATED AND DEMANDS INTEGRATION OF ALL PARTS FOR GOOD THERMAL CONTROL.

WHEN THE SUN PASSES THROUGH GLASS, IT IS TRAVELLING IN SHORT WAVELENGTHS. AS IT STRIKES AN INTERIOR SURFACE THE SHORT WAVE LENGTHS ARE CHANGED INTO LONG HEAT WAVE LENGTHS WHICH BEGIN TO WARM THE AIR. SINCE LONG WAVE LENGTHS PASS THROUGH GLASS ONLY BY CONDUCTION, HEAT BEGINS TO BUILD UP INSIDE THE SPACE. THIS IS THE "GREENHOUSE EFFECT".

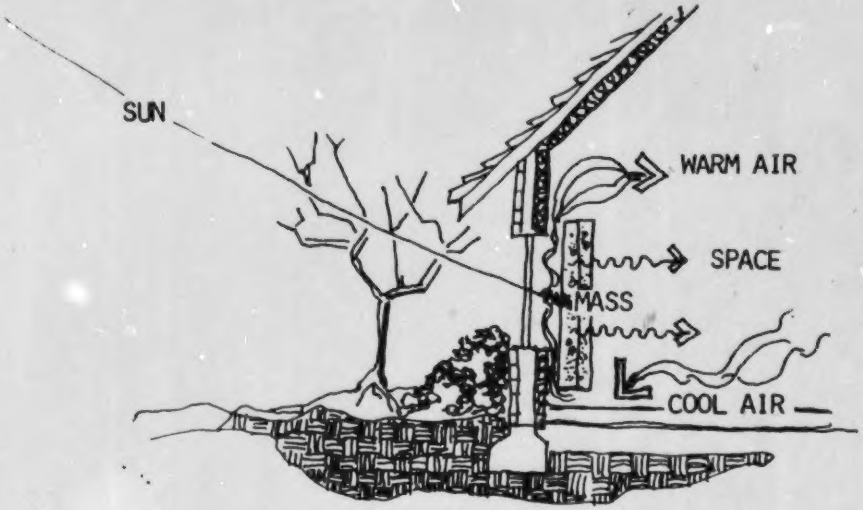
A THERMAL MASS WHICH IS INSULATED ON THE OUTSIDE WILL STORE THE INCOMING HEAT UNTIL THE INTERIOR TEMPERATURE DROPS BELOW THAT OF THE THERMAL MASS, AT WHICH TIME THE THERMAL MASS WILL BEGIN TO RELEASE ITS STORED HEAT.

WITH MOVEABLE INTERIOR INSULATION TO STOP THE FLOW OF HEAT FROM THE INSIDE TO THE OUTSIDE, AND WITH MOVEABLE EXTERIOR INSULATION TO STOP EXCESSIVE HEAT GAIN, A COMFORTABLE LEVEL OF CONTROL CAN BE REACHED.

IN EXISTING BUILDINGS A FEW SIMPLE ADDITIONS WILL ALLOW SOUTH FACING WINDOWS TO COLLECT VALUABLE HEAT. WHERE THE WINTER SUN WILL STRIKE THE INSIDE OF THE HOUSE, DARK SURFACES (TABLES, CHAIRS, ROCK PLANTERS, WATER BEDS) WILL ACT AS COLLECTORS. INSULATION ON BOTH INTERIOR AND EXTERIOR WILL FACILITATE CONTROL.

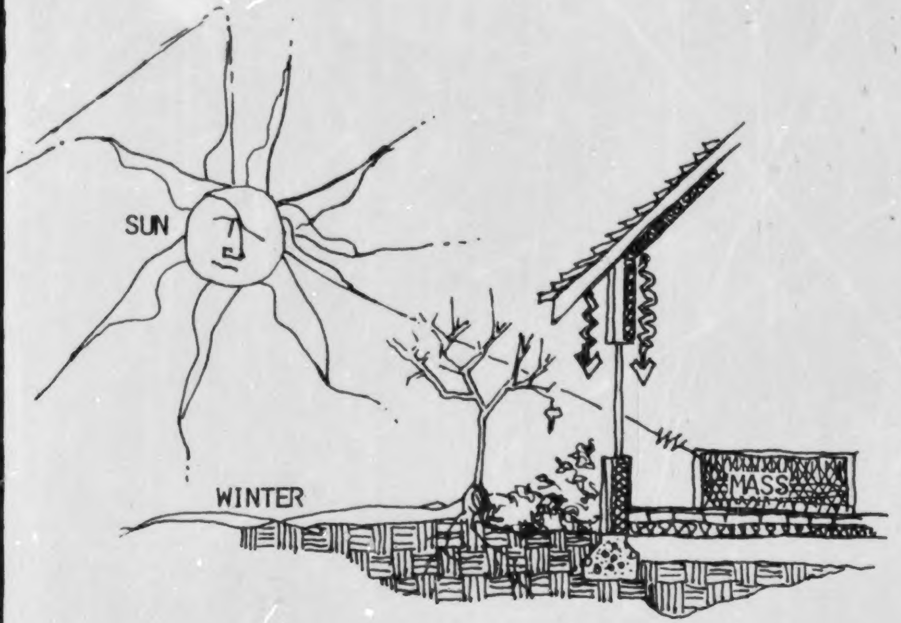


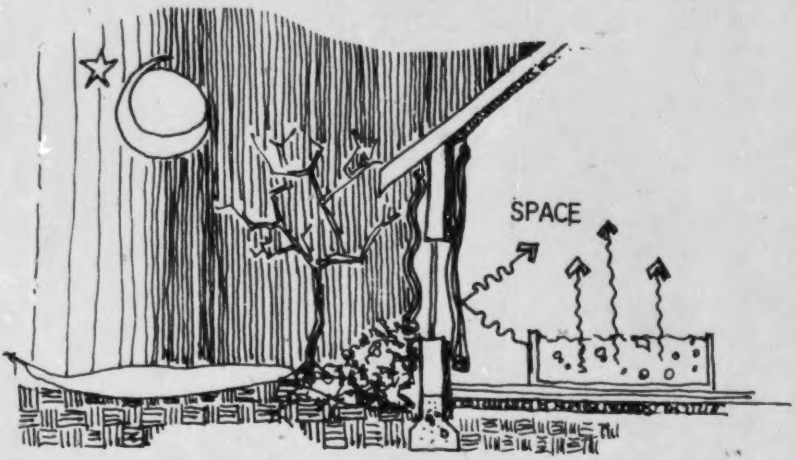
sun mass space



IN ANOTHER CONTEXT, AS THE SUN PASSES THROUGH GLASS AND STRIKES A THERMAL MASS, THE MASS IS SLOWLY WARMED AND STORES HEAT. A LARGE MASS HAS THE ABILITY TO STORE HEAT FOR A LONG TIME, RELEASING IT SLOWLY WHEN ITS TEMPERATURE BECOMES GREATER THAN THAT OF THE SURROUNDING AIR MASS.

AGAIN, MOVEABLE INTERIOR AND EXTERIOR INSULATION AS WELL AS VENTING SYSTEMS ALLOW MAXIMUM CONTROL WHILE CLIMATIC TIMETABLES HELP TO DETERMINE THE SIZE OF THE THERMAL MASS AND THE AMOUNT OF STORAGE NECESSARY FOR PERIODS OF LIMITED SUNSHINE.



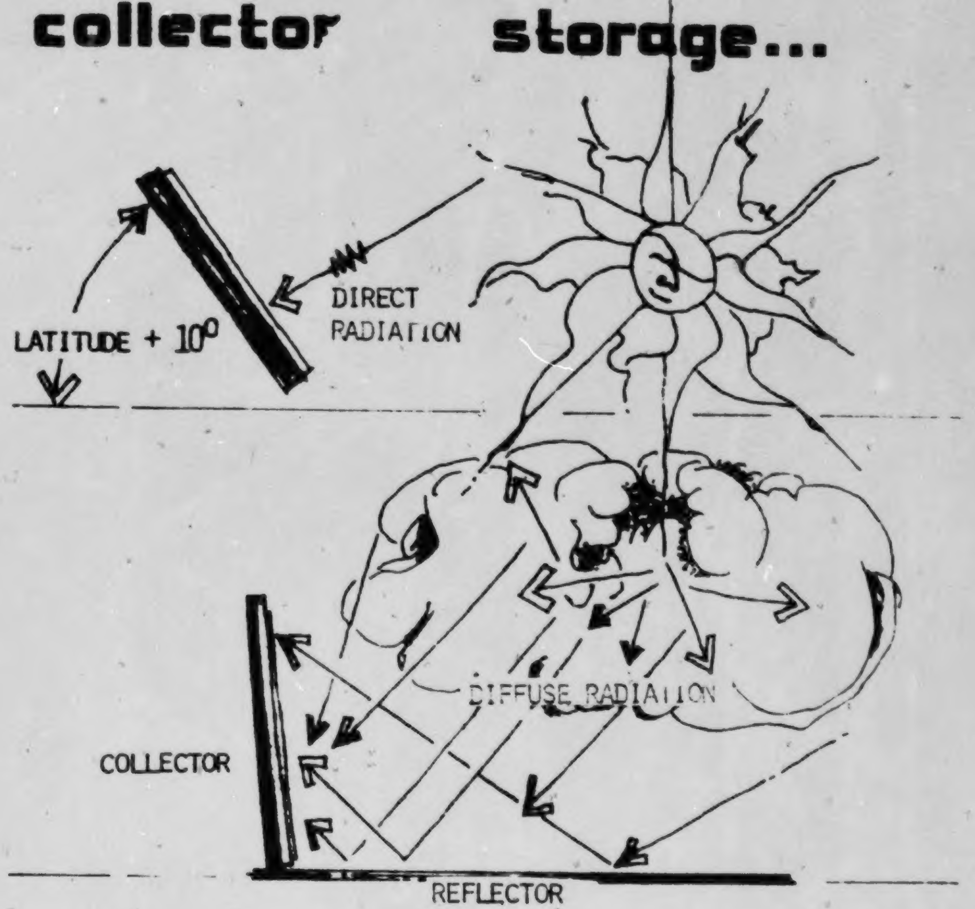


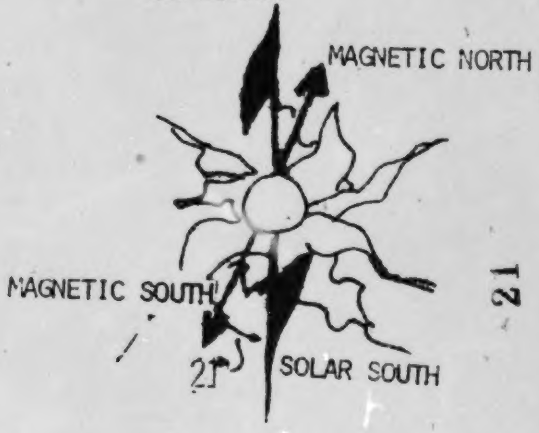
sun collector storage...

IN THE PRECEEDING EXAMPLES OF COLLECTION SYSTEMS, THE PARTS ARE HIGHLY INTEGRATED AND NOT EASILY SEPARABLE FROM THE TOTAL DESIGN OF THE BUILDING. SINCE MOST HOUSES WERE NOT BUILT TO COLLECT SOLAR HEAT, THOSE SYSTEMS WHICH CAN BE SEPARATED INTO DISTINCT UNITS (SUN, COLLECTOR, STORAGE SPACE) ARE OFTEN MOST ADAPTABLE TO EXISTING BUILDINGS.

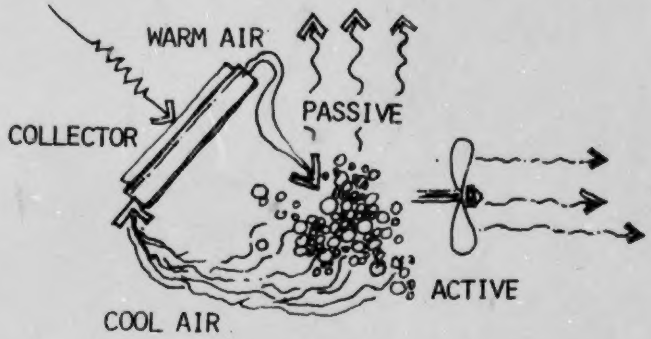
ONE OF THE FIRST CONSIDERATIONS IS TO DETERMINE THE ANGLE OF THE COLLECTION SURFACE TO THE SUN'S RAYS. THERE IS NO ONE OPTIMUM ANGLE AT WHICH TO PLACE THE COLLECTOR BUT THERE ARE TWO RELIABLE SOLUTIONS. ONE METHOD IS TO ORIENT THE COLLECTOR TEN TO FIFTEEN DEGREES GREATER THAN THE LATITUDE FROM THE HORIZONTAL. THIS METHOD ALLOWS COLLECTION OF THE GREATEST AMOUNT OF DIRECT SOLAR RADIATION DURING THE WINTER MONTHS BUT DOES NOT COLLECT MUCH DIFFUSE RADIATION ON CLOUDY DAYS. ANOTHER METHOD IS TO USE A NEARLY VERTICAL COLLECTOR WITH A NEARLY HORIZONTAL REFLECTOR. THE ADVANTAGE OF A REFLECTOR SEEMS TO BE THAT DIFFUSE AS WELL AS DIRECT RADIATION IS COLLECTED IN WINTER.

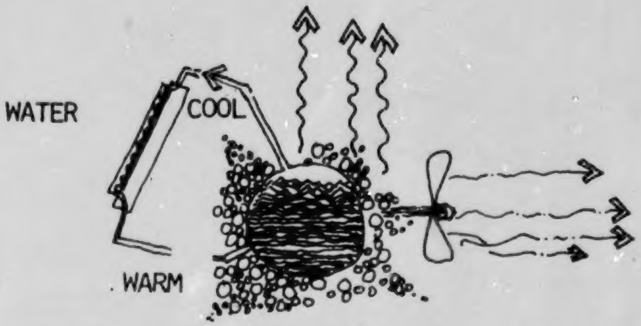
IN ADDITION THE COLLECTOR SHOULD BE ORIENTED TOWARDS TRUE OR SOLAR SOUTH OR SLIGHTLY WEST OF IT. IN EUGENE, TRUE OR SOLAR SOUTH IS 21 DEGREES EAST OF MAGNETIC SOUTH.

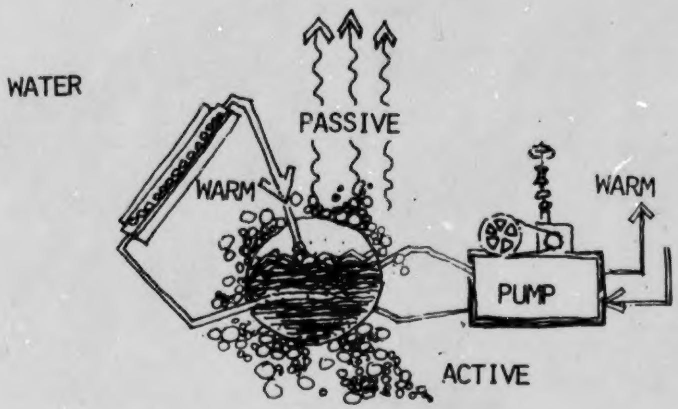




....space







COLLECTION

COLLECTORS MAY TAKE MANY FORMS IN MANY LOCATIONS; ROOFS, WALLS, FENCES, FREE STANDING SHELTERS. AIR, WATER, OR OTHER FLUIDS MAY BE USED AS TRANSFER MEDIA.

STORAGE

COLLECTED HEAT CAN BE STORED IN THERMAL MASSES WHICH MAY TAKE MANY FORMS. ROCKS, EARTH AND WATER ARE THE MOST COMMON. IN EXISTING BUILDINGS MANY POSSIBILITIES ARE PROVIDED BY "ANYTHING" WHICH WILL HOLD HEAT.

DISTRIBUTION

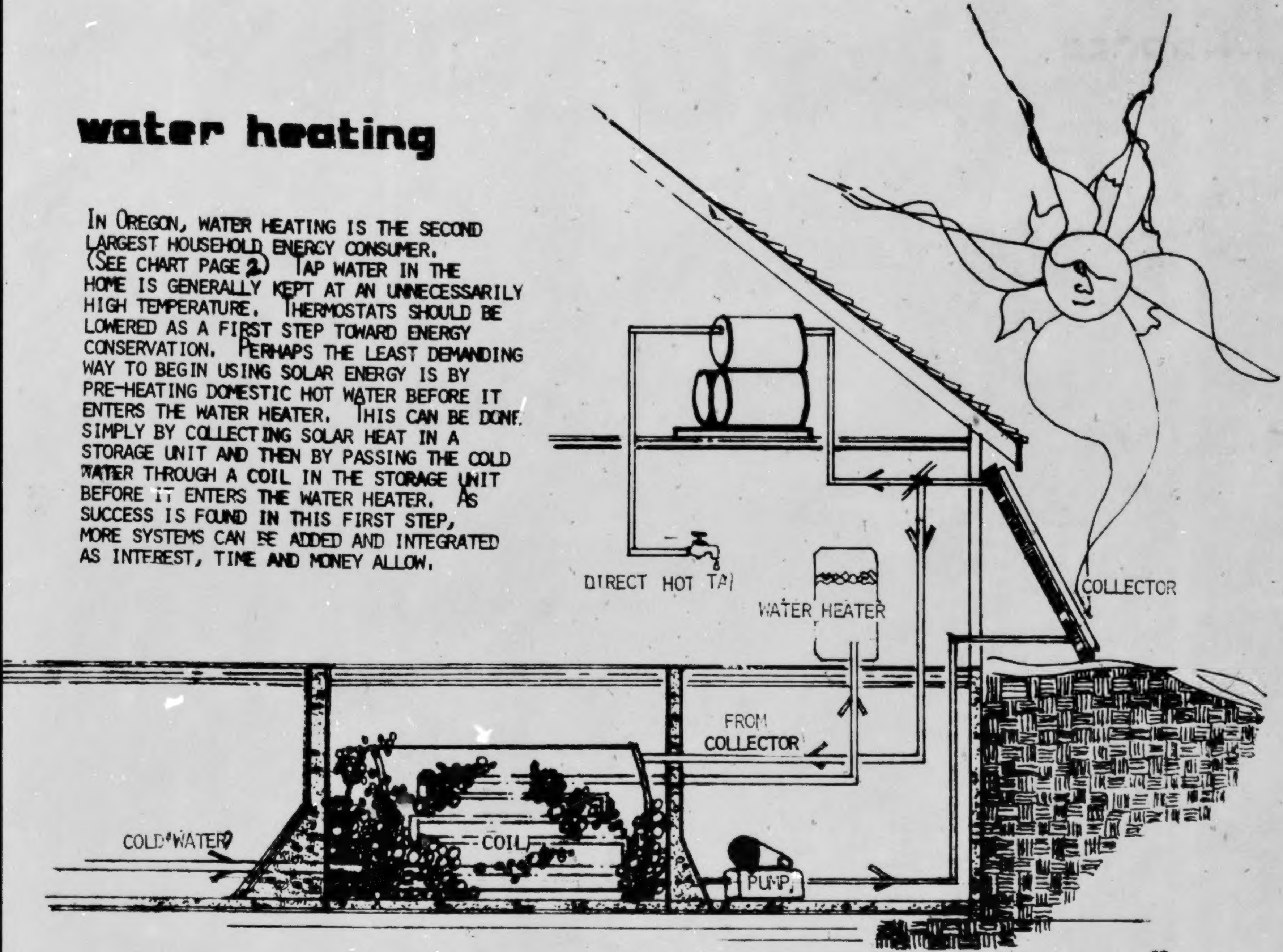
TRANSFER OF HEAT CAN OCCUR IN MANY WAYS; MECHANICALLY BY WATER PUMPS, RADIATORS OR FANS, OR SIMPLY BY ALLOWING STORED HEAT TO DISTRIBUTE ITSELF BY CONVECTION. EXISTING HEAT DUCTS OR RADIATORS CAN ALSO BE INCORPORATED INTO THE DISTRIBUTION SYSTEM.

CONTROL

CONTROL OF THE WHOLE SYSTEM CAN BE ACCOMPLISHED MANUALLY OR ELECTRICALLY WITH VALVES VENTS AND THERMOSTATS. INSULATION BOTH FIXED AND MOVEABLE CAN BE EMPLOYED TO CONTROL HEAT BETWEEN THE COLLECTOR, THE STORAGE UNIT AND THE LIVING SPACE.

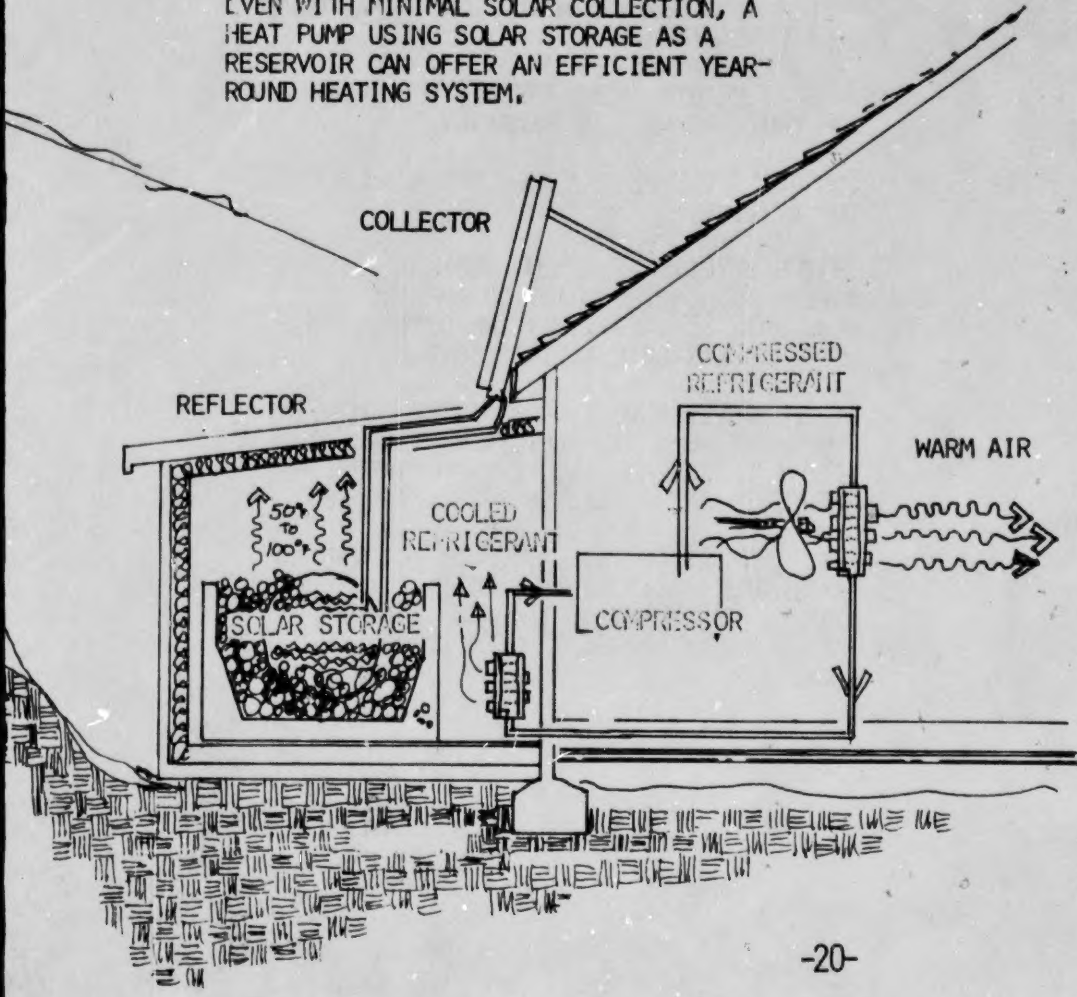
water heating

IN OREGON, WATER HEATING IS THE SECOND LARGEST HOUSEHOLD ENERGY CONSUMER. (SEE CHART PAGE 2) TAP WATER IN THE HOME IS GENERALLY KEPT AT AN UNNECESSARILY HIGH TEMPERATURE. THERMOSTATS SHOULD BE LOWERED AS A FIRST STEP TOWARD ENERGY CONSERVATION. PERHAPS THE LEAST DEMANDING WAY TO BEGIN USING SOLAR ENERGY IS BY PRE-HEATING DOMESTIC HOT WATER BEFORE IT ENTERS THE WATER HEATER. THIS CAN BE DONE SIMPLY BY COLLECTING SOLAR HEAT IN A STORAGE UNIT AND THEN BY PASSING THE COLD WATER THROUGH A COIL IN THE STORAGE UNIT BEFORE IT ENTERS THE WATER HEATER. AS SUCCESS IS FOUND IN THIS FIRST STEP, MORE SYSTEMS CAN BE ADDED AND INTEGRATED AS INTEREST, TIME AND MONEY ALLOW.


DIRECT HOT TAP
WATER HEATER
COLLECTOR
FROM COLLECTOR
COLD WATER
COIL
PUMP

heat pumps

EVEN WITH MINIMAL SOLAR COLLECTION, A HEAT PUMP USING SOLAR STORAGE AS A RESERVOIR CAN OFFER AN EFFICIENT YEAR-ROUND HEATING SYSTEM.



A HEAT PUMP IS A DEVICE WHICH TRANSFERS HEAT FROM A COLDER RESERVOIR (THE OUTSIDE AIR) TO A WARMER ONE (THE INSIDE AIR) BY MECHANICAL ENERGY IN A REVERSED REFRIGERATION PROCESS.

FOR INSIDE SPACE HEATING, A REFRIGERANT IS COMPRESSED BY MECHANICAL ENERGY AND HEAT IS GIVEN OFF TO INSIDE SPACE BY RADIATION. WHEN THIS HEAT IS GIVEN OFF TO THE INSIDE AIR, THE REFRIGERANT IS ALLOWED TO EXPAND, COOL, AND PICK UP HEAT FROM A RESERVOIR (THE OUTSIDE AIR). WHEN HEAT IS PICKED UP BY THE EXPANDED REFRIGERANT, THE RESERVOIR IS COOLED AND THE COLLECTED HEAT FROM THE RESERVOIR IS AGAIN GIVEN UP TO INSIDE SPACE BY COMPRESSING THE REFRIGERANT.

A HEAT RESERVOIR CAN BE THE OUTSIDE AIR (WHEN IT IS ABOVE FREEZING) OR IT CAN BE SOME OTHER THERMAL MASS SUCH AS A STORAGE TANK ACCEPTING HEAT FROM A SOLAR COLLECTOR, COILS IN A FIREPLACE OR WOOD STOVE, OR ANY NUMBER OF OTHER HEAT SOURCES.

THE ADVANTAGE OF A HEAT PUMP IS THAT IT CAN USE A LOW TEMPERATURE HEAT SOURCE AND BOOST AIR TEMPERATURE TO A MORE COMFORTABLE LEVEL BY USING ELECTRICITY ONLY TO OPERATE A PUMP AND NOT TO HEAT ELECTRIC RESISTORS (BASE BOARD HEATERS). IT REQUIRES ABOUT THREE TIMES AS MUCH ENERGY IN THE FORM OF ELECTRICITY TO HEAT A SPACE WITH RESISTORS AS IT DOES TO OPERATE A HEAT PUMP.

ANALYZING A SITE FOR SOLAR COLLECTOR SUITABILITY

FIRST, EXPLORE THE SITE TO DETERMINE WHICH LOCATION HAS THE BEST COMBINATION OF OPEN VIEW TOWARDS DUE SOUTH, AND OPEN VIEW OF THE ENTIRE SKY DOME. IF THE SKYLINE IS LOW, THAT IS WITH NO TALL TREES, ADJACENT BUILDINGS, ABRUPTLY RISING HILLS, OR OTHER OBSTRUCTIONS, THE FOLLOWING PROCEDURE IS UNNECESSARY.

USING:

A COMPASS FOR BEARING READINGS,
A SURVEYOR'S HAND LEVEL FOR ALTITUDE READINGS,
A PENCIL AND THE "44° SUN CHART";

PLACE YOURSELF AT THE APPROXIMATE CENTER OF WHERE YOU THINK THE COLLECTOR WILL BE. THIS MAY REQUIRE A LADDER, AS MANY COLLECTORS ARE PART OF THE ROOF SYSTEM.

FIND THE ALTITUDE OF THE SKYLINE AS FOLLOWS:

> DETERMINE WHICH DIRECTION (BEARING) IS DUE SOUTH. (DUE SOUTH WILL BE ABOUT 21° EAST OF MAGNETIC SOUTH IN THE WILLAMETTE VALLEY.)
>
> AIMING YOUR HAND LEVEL DUE SOUTH, DETERMINE THE ALTITUDE (ANGLE ABOVE THE HORIZONTAL) OF THE SKYLINE. (THE SKYLINE IS THE TOP OF THE HIGHEST OBSTRUCTION AT A GIVEN BEARING.) ON THE CHART, WRITE THIS ANGLE BELOW "0° SOUTH" ON THE SCALE OF BEARINGS AT THE BOTTOM OF THE CHART.
>
> SIMILARLY, FIND AND RECORD THE ALTITUDES OF SKYLINE FOR EACH 15° BEARING, BOTH EAST AND WEST OF SOUTH, TO AT LEAST 105° (THIS IS A TOTAL OF 15 ALTITUDE READINGS.)
>
> FOR ISOLATED OBJECTS SUCH AS TALL TREES, FIND BOTH THE BEARING AND THE ALTITUDE FOR EACH OBJECT, AND RECORD AT APPROPRIATE BEARINGS.

ON BOTH CHARTS, PLOT THE ALTITUDE READINGS FOR THEIR RESPECTIVE BEARINGS.

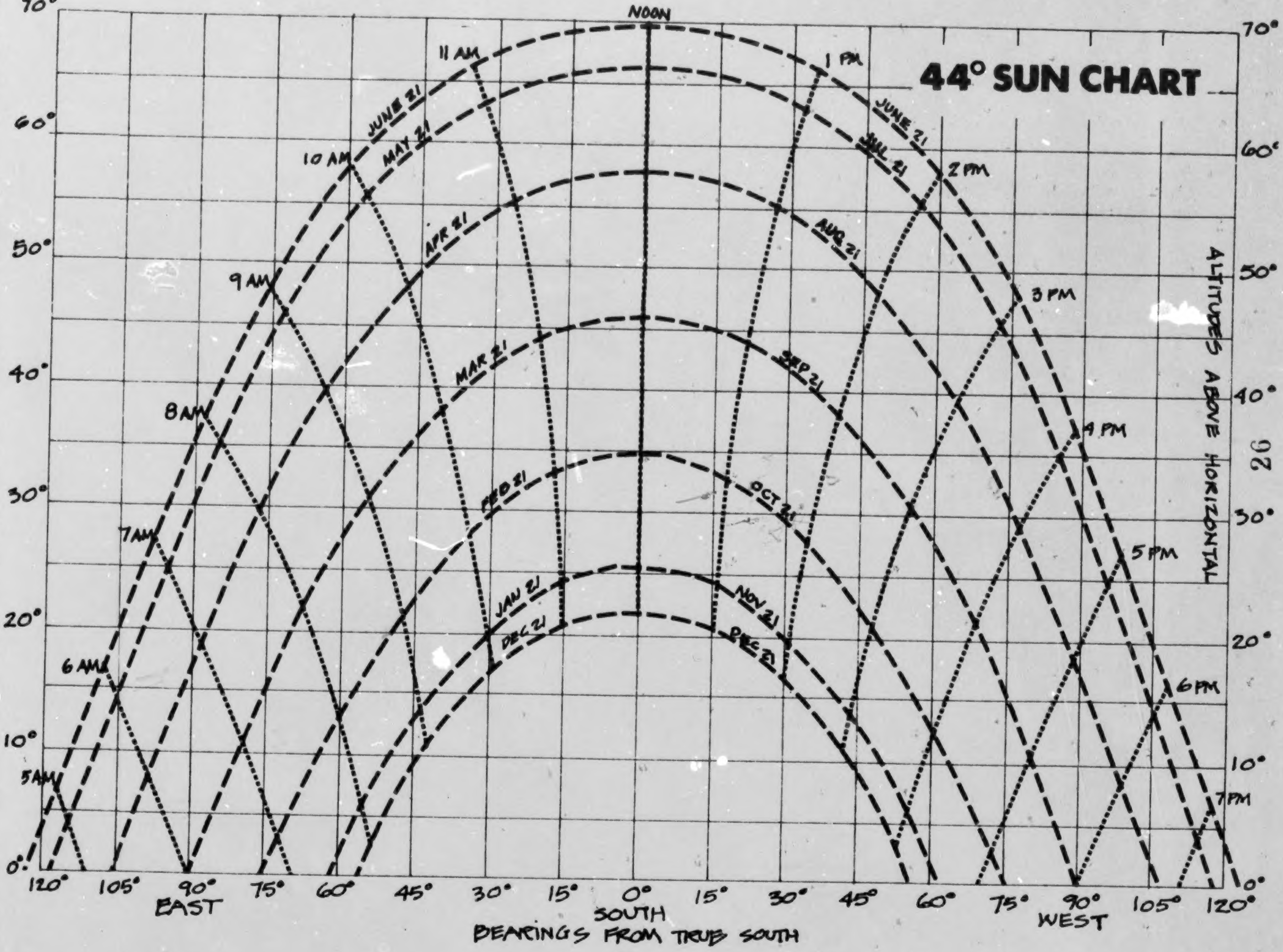
CONNECT THESE PLOTS; THE LINE RESULTING IS THE SKYLINE.

IF THE SKYLINE IS SO LOW THAT IT DOES NOT APPEAR WITHIN THE CHART OR APPEARS ONLY AT LESS THAN 15° ALTITUDE, THE OBSTRUCTIONS TO USEFUL SOLAR GAIN ARE NEGLIGIBLE.

IF THE SKYLINE OBSTRUCTS WINTER SUN WITHIN THE CHART ABOVE 15° ALTITUDE, THERE WILL BE LESS SOLAR ENERGY INCOME THAN OTHERWISE EXPECTED, AND COLLECTOR SIZE INCREASES.

MORE DETAILS ON INSOLATION BY HOUR AND BY MONTH ARE AVAILABLE IN "SOLAR ENERGY FOR PACIFIC NORTHWEST BUILDINGS," ALSO PUBLISHED BY THE CENTER FOR ENVIRONMENTAL RESEARCH.

44° SUN CHART


NOON
11 AM
1 PM
10 AM
2 PM
9 AM
3 PM
8 AM
4 PM
7 AM
5 PM
6 AM
6 PM
5 AM
7 PM
JUNE 21
MAY 21
APR 21
MAR 21
FEB 21
JAN 21
DEC 21
JUNE 21
JUL 21
AUG 21
SEP 21
OCT 21
NOV 21
DEC 21
70°
60°
50°
40°
30°
20°
10°
0°
120°
105°
90°
75°
60°
45°
30°
15°
0°
15°
30°
45°
60°
75°
90°
105°
120°
EAST
SOUTH
WEST
BEARINGS FROM TRUE SOUTH
ALTITUDES ABOVE HORIZONTAL

HOW TO USE THIS CHART

THE PURPOSE OF THIS CHART IS TO PROVIDE ROUGH SIZES OF COLLECTORS AND STORAGE TANKS BY SIMPLY KNOWING THE HEATING NEEDS OF THE HOUSE.

FOLLOW THE LARGE CIRCLED NUMBERS FROM 1-6.

IF HEAT LOSS HAS NOT BEEN FIGURED, METHOD II UNDER ① CAN BE USED. ① IS LOSS FOR A BAD WINTER HOUR AND MUST BE ADJUSTED TO A 24 HOUR DAY.

HEAT GAIN FROM APPLIANCES SHOULD ALSO BE CONSIDERED. LIGHTS, OVEN, AND THE WATER HEATER (IF IT'S INSIDE THE HOUSE) ARE A FEW THAT ADD HEAT TO THE HOUSE. THE VALUE FOR APPLIANCE HEAT GAIN CAN BE SUBTRACTED FROM **c** (BTU/DAY).

EACH NUMBER WITH THE SAME LARGE LETTER IS THE SAME NUMBER AND CAN BE FILLED INTO THE DIAGRAM. (ALL **d**'S ARE THE SAME NUMBER.)

THIS PROCEDURE WAS DEVISED BY FRED KEPPEL, CONSULTING MECHANICAL ENGINEER AND SOLAR HEATING DESIGNER.

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. $\sum(\Delta T)(\text{Area})(U) =$ **g** ______BTU/H

g ______BTU/H ÷ ______Floor Area= **a** __________BTU/H/Ft^2

II. **a** (____Factor)(________Floor Area)= **g** _______BTU/H

↑ 'Conserving House' = 25 BTU/H/Ft^2
'Typical House' = 40 BTU/H/Ft^2

② Heat Loss (BTU/DAY)

Winter Degree Days, Av=21/Day

$$\frac{(\textbf{a}\ \_\_\_\_\_\_\ \text{BTU/H/Ft}^2)(24\ \text{Hr.})}{(\_\_°\text{Inside Temp.} - \_\_\_°\text{Design Temp})} = \textbf{b}\ \_\_\_\_\_\ \text{BTU/Degree Day/Ft}^2$$

b (_____BTU/Degree Day/Ft^2)(____Fl. Area)(21 Degree Days)= **c** _________BTU/DAY

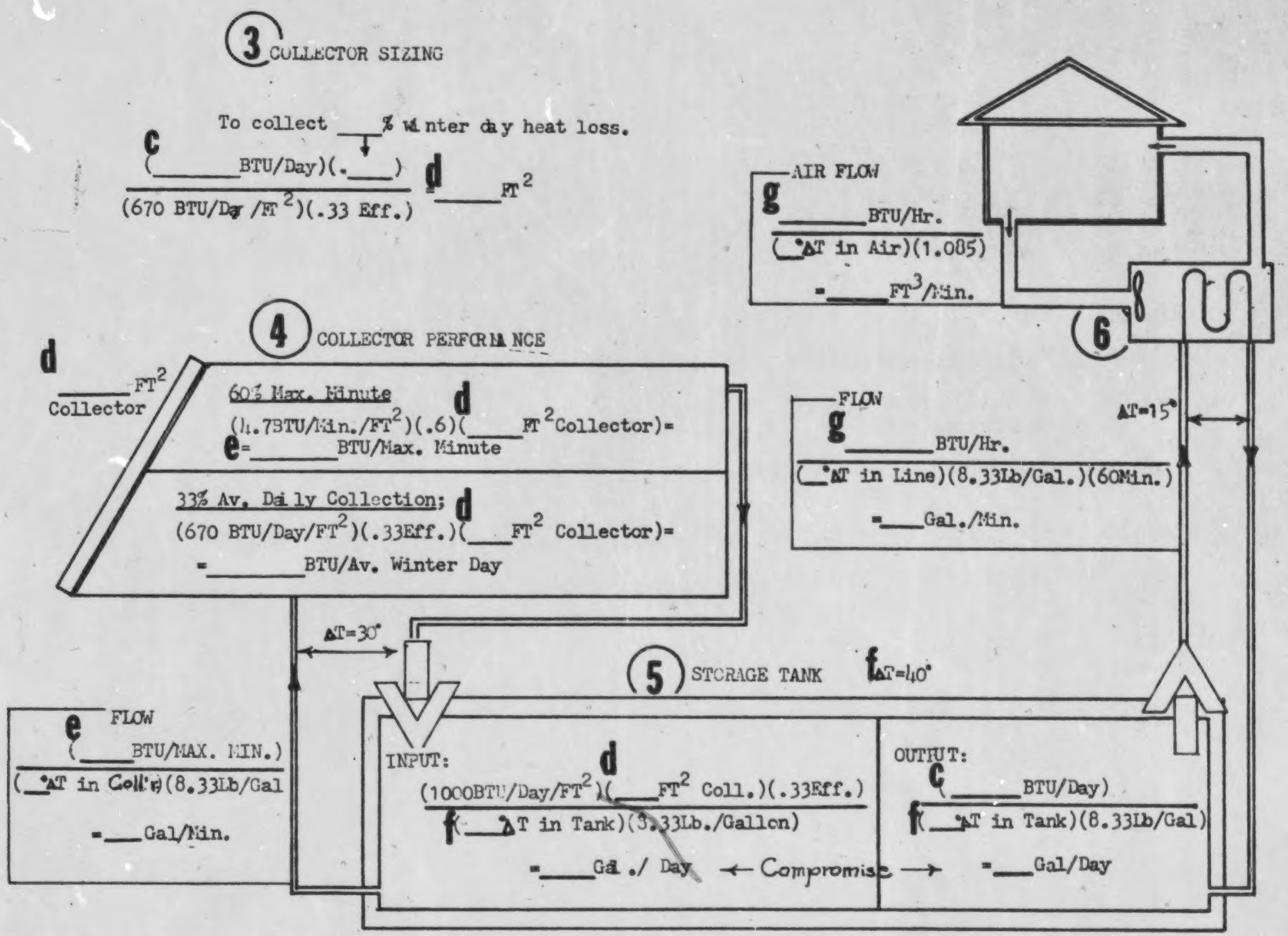
Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

Insolation Data: (per Ft^2 of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft^2

Av. Winter Day = 670 BTU/Day/Ft^2

Max. Winter Day (100%)= 1000 BTU/Day/Ft^2



③ COLLECTOR SIZING

To collect ___% winter day heat loss.

$$\frac{\overset{c}{(\_\_\_\_\_\ \text{BTU/Day})}(.\_\_\_)}{(670\ \text{BTU/Day/FT}^2)(.33\ \text{Eff.})} \overset{d}{=} \_\_\_\_\ \text{FT}^2$$

④ COLLECTOR PERFORMANCE

d ______FT² Collector

60% Max. Minute

$(4.7\text{BTU/Min./FT}^2)(.6)(\overset{d}{\_\_\_\_}\ \text{FT}^2\ \text{Collector}) =$

$\overset{e}{=}\_\_\_\_\_\ \text{BTU/Max. Minute}$

33% Av. Daily Collection;

$(670\ \text{BTU/Day/FT}^2)(.33\text{Eff.})(\overset{d}{\_\_\_\_}\ \text{FT}^2\ \text{Collector}) =$

$= \_\_\_\_\_\ \text{BTU/Av. Winter Day}$

FLOW

$$\frac{\overset{e}{(\_\_\_\_\ \text{BTU/MAX. MIN.})}}{(\_\_°\Delta T\ \text{in Coll'r})(8.33\text{Lb/Gal}} = \_\_\_\ \text{Gal/Min.}$$

⑤ STORAGE TANK

$\overset{f}{\Delta T}=40°$

INPUT:

$$\frac{(1000\text{BTU/Day/FT}^2)(\overset{d}{\_\_\_}\ \text{FT}^2\ \text{Coll.})(.33\text{Eff.})}{\overset{f}{(}\_\_\_\Delta T\ \text{in Tank})(8.33\text{Lb./Gallon})} = \_\_\_\_\ \text{Gal./Day}$$

← Compromise →

OUTPUT:

$$\frac{\overset{c}{(}\_\_\_\_\_\ \text{BTU/Day})}{\overset{f}{(}\_\_\_°\Delta T\ \text{in Tank})(8.33\text{Lb/Gal})} = \_\_\_\ \text{Gal/Day}$$

⑥

FLOW

$$\frac{\overset{g}{\_\_\_\_\_}\ \text{BTU/Hr.}}{(\_\_°\Delta T\ \text{in Line})(8.33\text{Lb/Gal.})(60\text{Min.})} = \_\_\_\ \text{Gal./Min.}$$

AIR FLOW

$$\frac{\overset{g}{\_\_\_\_\_}\ \text{BTU/Hr.}}{(\_\_°\Delta T\ \text{in Air})(1.085)} = \_\_\_\_\ \text{FT}^3\text{/Min.}$$

SOURCES:

PAGE 1: OFFICE OF ENERGY RESEARCH AND PLANNING, STATE OF OREGON, TRANSITION. JANUARY 1975, CHART 4.

PAGE 2: IBID, CHART 34.

PAGE 3: VICTOR OLGYAY, DESIGN WITH CLIMATE, (PRINCETON UNIVERSITY PRESS, 1973), FIGURE 46.

PAGE 4: JOHN S. REYNOLDS, SOLAR ENERGY FOR PACIFIC NORTHWEST BUILDINGS, (UNIVERSITY OF OREGON, CENTER FOR ENVIRONMENTAL RESEARCH, FEB '76 EDITION) PP. 32 AND 59.

PAGE 5: IBID, P. 4, 5.

EUGENE WATER AND ELECTRIC BOARD, 1972 FACTS AND FIGURES, P. 24.

PAGE 6: OP. CIT., JOHN S. REYNOLDS, P. 17.
RATE FIGURES FROM LOCAL UTILITIES 1960-1975.

PAGE 9: WILLIAM J. MCGUINNESS, MECHANICAL AND ELECTRICAL EQUIPMENT FOR BUILDINGS, (NEW YORK: JOHN WILEY AND SONS, INC., 1971), P. 182 (WINTER DESIGN TEMPERATURES).

PAGE 10: JOHN HANCOCK CALLENDER, TIME SAVER STANDARDS, (MCGRAW HILL, 1966), PP. 653-662.

PAGES 14-18: COLLEGE OF ARCHITECTURE, ARIZONA STATE UNIVERSITY, SOLAR-ORIENTED ARCHITECTURE, JANUARY 1975.

PAGES 21-22: OP. CIT., JOHN S. REYNOLDS, PP. 26-29.

PAGES 23-24: OP. CIT., JOHN S. REYNOLDS, PP. 30, 31 (A LATER VERSION OF THE SIZING PROCEDURE APPEARS IN THIS REFERENCE.)

GENERAL REFERENCES:

College of Architecture, Arizona State University, Solar-oriented Architecture, January, 1975.

John C. Moyers, The Value of Thermal Insulation in Residential Construction: Economics and the Conservation of Energy, (ORNL-NSF-EP-9) (Oakridge National Laboratory, December 1971).

The Office of Energy Research and Planning, Transition, (Office of the Governor, State of Oregon, 1975).

Oregon Alternative Energy Study Research Group, Oregon Alternative Energy Study, (Office of Energy Research and Planning, May 1975).

Portola Institute, Energy Primer, (Portola Institute 1974).

OTHER SOLAR PUBLICATIONS FROM THE CENTER FOR ENVIRONMENTAL RESEARCH:

Baker & Reynolds, Insolation on Tilted Surfaces for Pacific Northwest Locations (1975).

Gray & Baker, Survey of Solar Buildings, 2nd edition (1976).

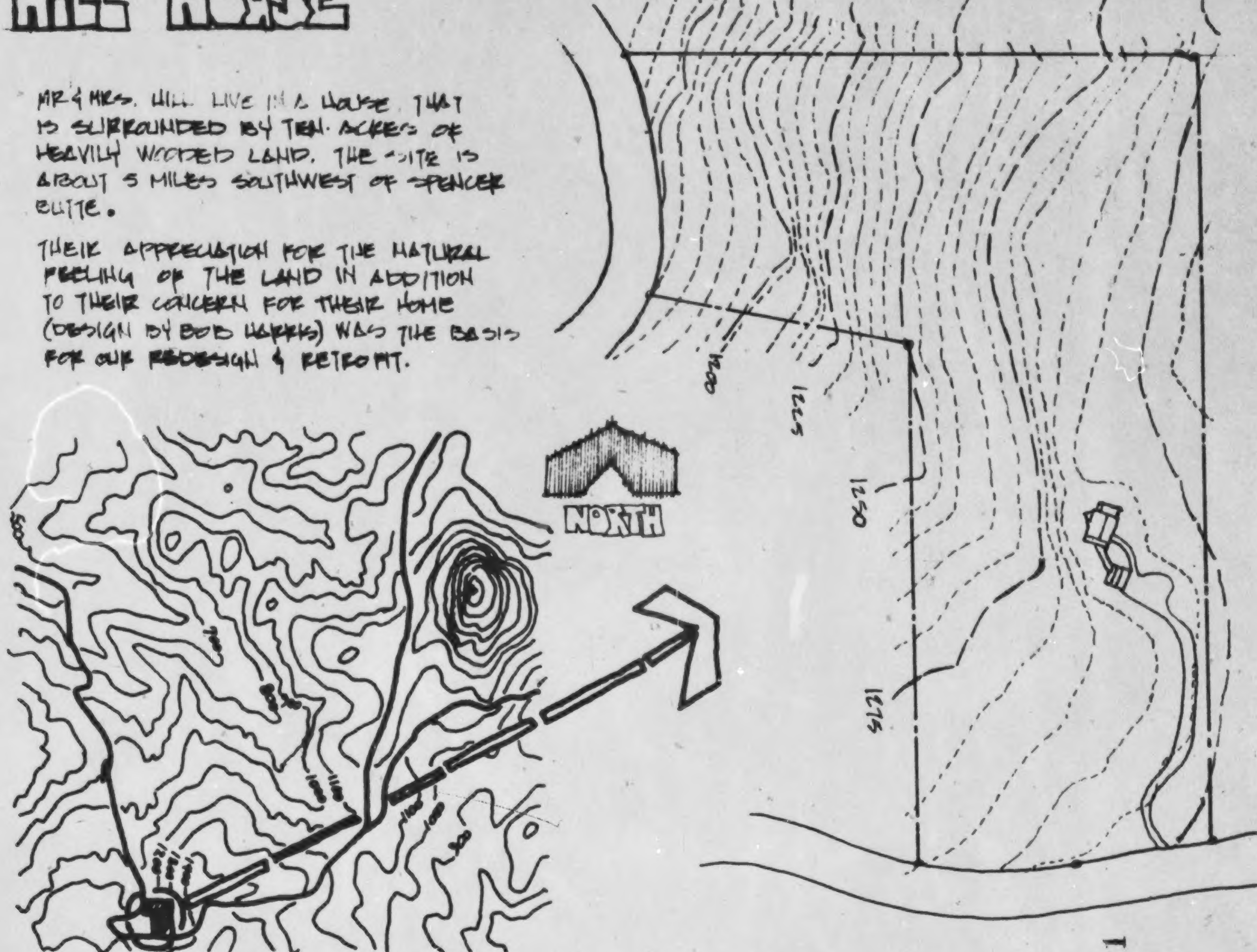
Reynolds, Larson, Baker, The Atypical Mathew Solar House at Coos Bay, Oregon (1975).

Reynolds, Solar Energy for Pacific Northwest Buildings, 4th edition (1976).

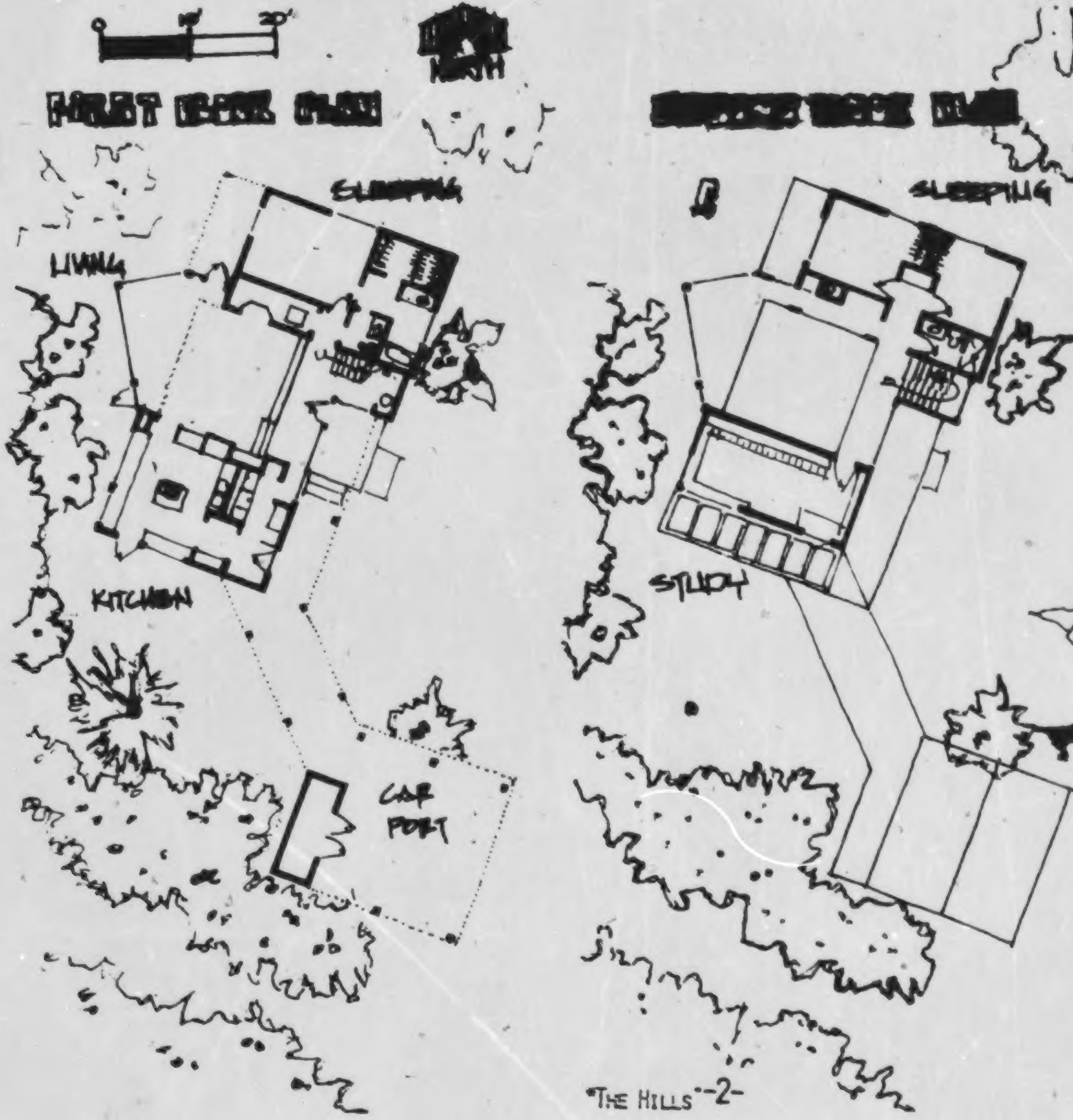
HILL HOUSE

MR & MRS. HILL LIVE IN A HOUSE THAT IS SURROUNDED BY TEN ACRES OF HEAVILY WOODED LAND. THE SITE IS ABOUT 5 MILES SOUTHWEST OF SPENCER BUTTE.

THEIR APPRECIATION FOR THE NATURAL FEELING OF THE LAND IN ADDITION TO THEIR CONCERN FOR THEIR HOME (DESIGN BY BOB HARRIS) WAS THE BASIS FOR OUR REDESIGN & RETROFIT.

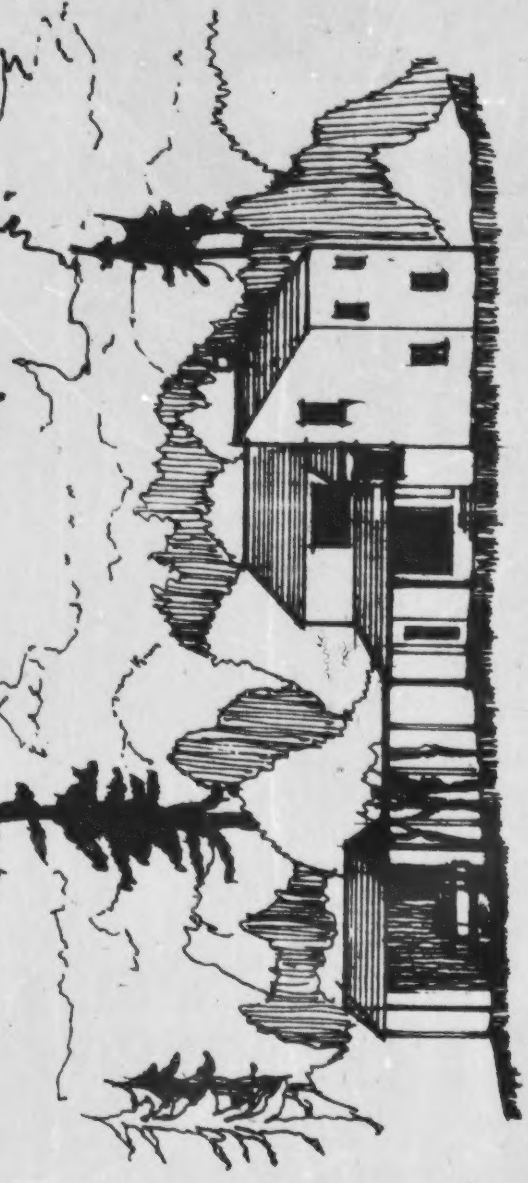

500
700
800
1100
1000
900
NORTH
1200
1225
1250
1275

FLOOR PLANS


0
10'
20'
NORTH
FIRST FLOOR PLAN
LIVING
SLEEPING
KITCHEN
CAR PORT
SECOND FLOOR PLAN
SLEEPING
STUDY

"THE HILLS" -2-

SITE SECTION



HOUSE DATA

AREAS

FLOOR AREA (1ST=1188, 2ND=778) = 1966 ft²
ROOF = 1366 ft²
INSULATED WALL = 2070 ft²
GLASS = 940 ft²
SKYLIGHT = 143 ft²

VOLUMN

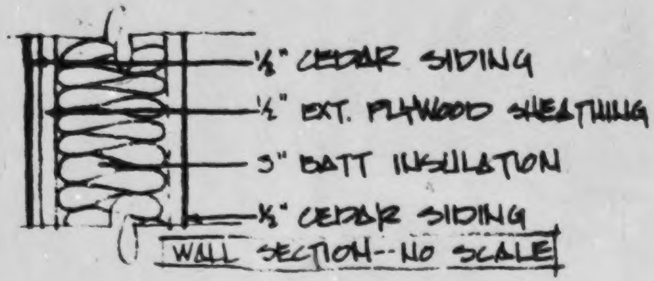
WHOLE HOUSE TOTAL = 23780 ft³
LIVING AREA = 16500 ft³

DESIGN TEMPERATURE

FOR SURFACES FACING THE EXTERIOR
$\Delta t = 65° - 15° = 50°$
FOR FLOOR FACING INTO CLOSED CRAWL SPACE
$\Delta t = 65° - 30° = 35°$

HEAT LOSS

INSULATED WALL


½" CEDAR SIDING
½" EXT. PLYWOOD SHEATHING
3" BATT INSULATION
½" CEDAR SIDING

WALL SECTION--NO SCALE

AREA = 2070 ft²

RESISTANCE "R"
OUTSIDE AIR FILM = .17
½" CEDAR SIDING = $\frac{1.25}{2}$ = .64
½" EXT. PLYWOOD SHEATING = $\frac{1.25}{2}$ = .64
3" BATT INSULATION = 3.12 x 3 = 9.36
½" CEDAR SIDING = $\frac{1.25}{2}$ = .64
INSIDE AIR FILM = .68

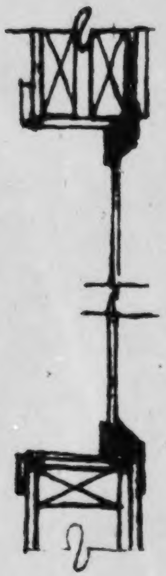
TOTAL R = 11.46

$"U" = 1/R = \frac{1}{11.46} = .0874$

AREA x "U" x Δt = BTUH LOSS

2070 ft² x .0874 x 50 = 9040 BTUH LOSS

VERTICAL GLASS



WALL SECTION AT WINDOW

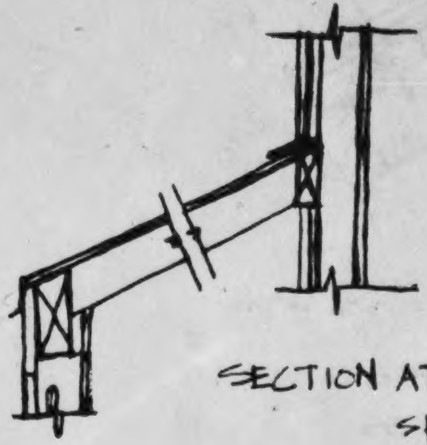
"U" FOR SINGLE PANE ¼" GLASS = 1.13

GLASS AREA = 940ft²

940ft² × 1.13 × 50 = 53100 BTUH LOSS

THE BIGGEST HEAT LOSER!

SKYLIGHT



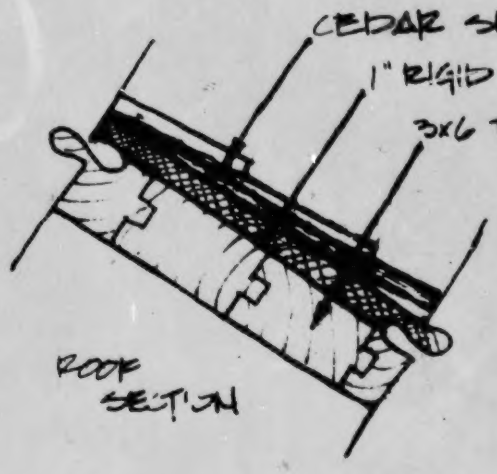
SECTION AT KITCHEN
SKYLIGHT

AREA OF SINGLE PANE = 143 ft²

"U" FOR SINGLE PANE = 1.13

143 × 1.13 × 50 = 8720 BTUH LOSS

ROOF


CEDAR SHINGLES
1" RIGID INSULATION
3x6 T&G DECK

ROOF SECTION

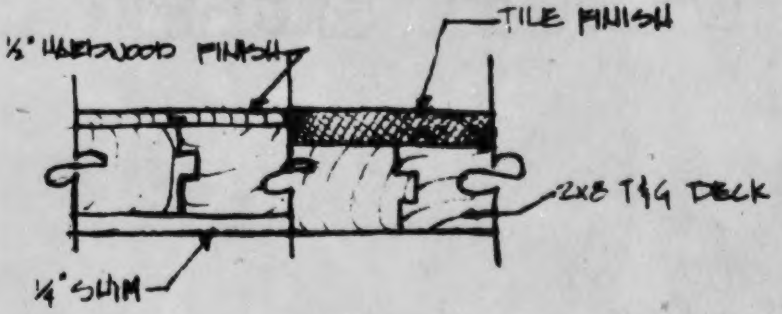
AREA OF ROOF = 1306 ft²

	"R"
OUTSIDE AIR FILM	= .17
CEDAR SHINGLES	= .94
1" RIGID INSULATION	= 2.78
3" WOOD DECK	= 3.28
INSIDE AIR FILM	= .68
	TOTAL = 7.85

$U = \frac{1}{7.85} = .127$

1306 x .127 x 50 = 8293 BTUH L[illegible]

FLOOR


½" HARDWOOD FINISH
TILE FINISH
2x8 T&G DECK
¼" SHIM

FLOOR SECTIONS

FLOOR AREA = 1167 ft²
TILE AREA = 788 ft²
HARDWOOD = 379 ft²

Δt = 35°

	"R"
HARDWOOD FLOOR	= .91/2 = .46
2x8 FLOOR DECK	= 1.25 x 2 = 2.50
	TOTAL = 2.95
	"U" $\frac{1}{2.95}$ = .338
TILE FLOOR	= .04
2x8 FLOOR DECK	= 2.50
	TOTAL = 2.54
	"U" = $\frac{1}{2.54}$ = .393

HARDWOOD BTUH = 379 x .338 x 35 = 4483 BTUH

TILE BTUH = 788 x .393 x 35 = 10839 BTUH

-TAL BTUH THROUGH FLOOR =

-330 BTUH LOSS

LUNG LOSS

1 AIR CHANGE PER HOUR

LUNG LOSS = .018 x Δt x VOL.

.018 x 50 x 23780 = 21400 BTU/HR.

$\frac{21400}{1966}$ = 10.8/HR/FT² FLOOR AREA

TOTAL SKIN LOSS

ITEM	BTUH
WALL	9040
VERTICAL GLASS	53100
SKYLIGHT	8720
ROOF	8293
FLOOR	15330
	94,483 BTU/HR

PER HOUR

TOTAL 115,883 BTU/HR.

BTU/HR/ft²

115,900/1966 = 58.85

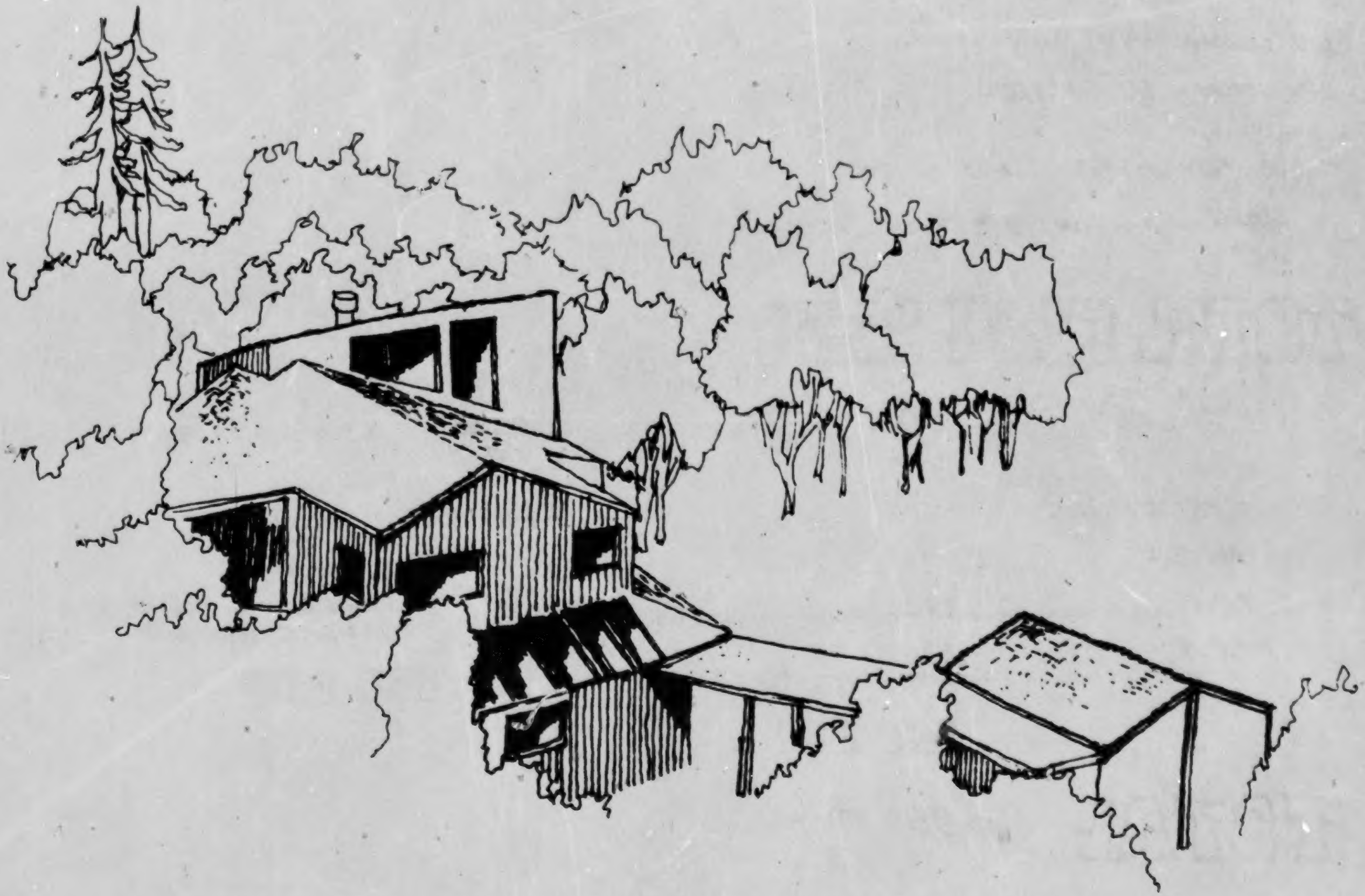
$\frac{58.85 \times 24}{50}$ = 28.25 BTU/DEG.DAY/ft²

28.25 x 1966 x 21 DEG.DAYS = 1,166,000

1,166,000
− 130,000 APPLIANCE GAIN
1,036,000 BTU/DAY

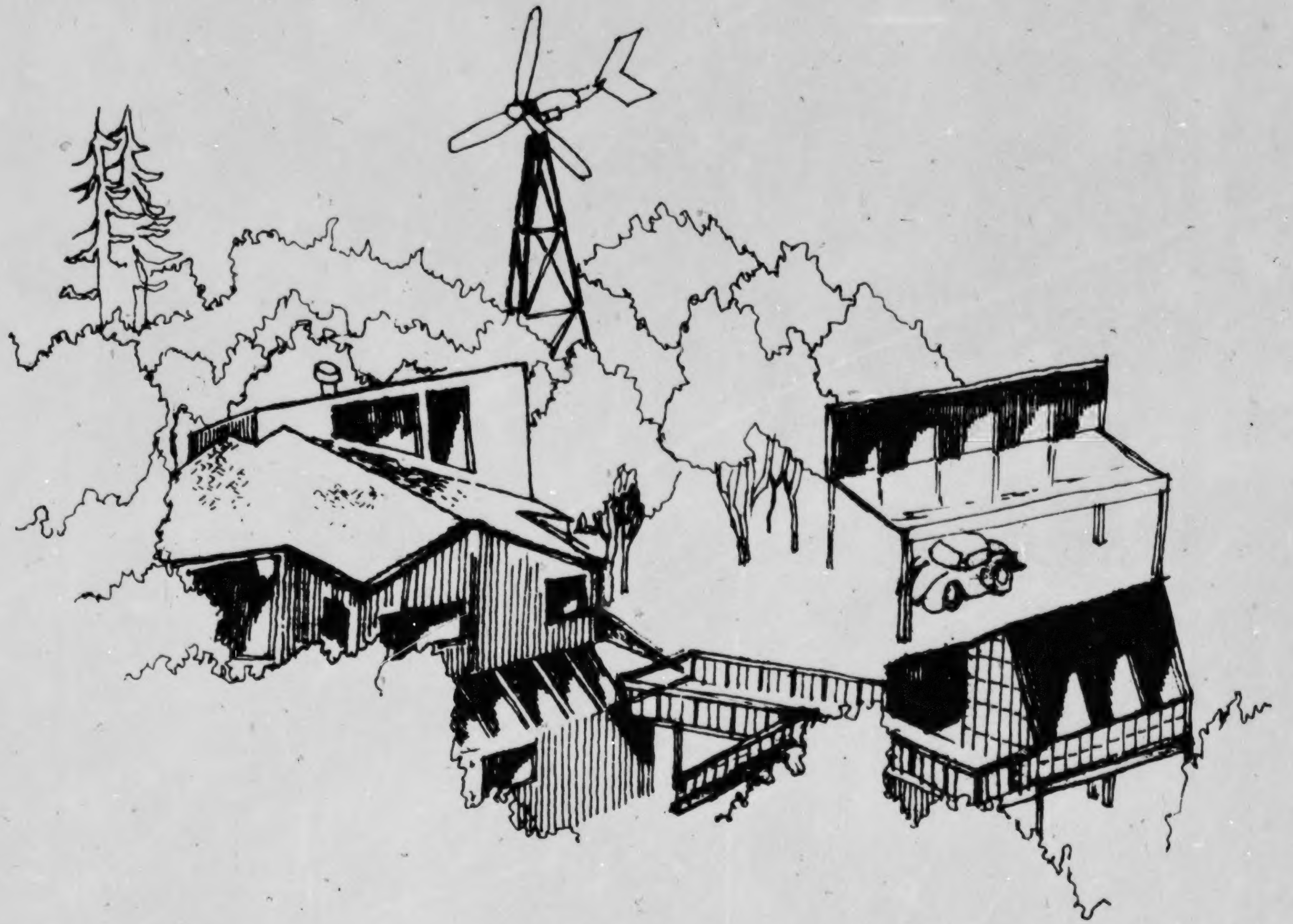
PER DAY

AS IS



"THE HILLS -7-

RETRO-FIT

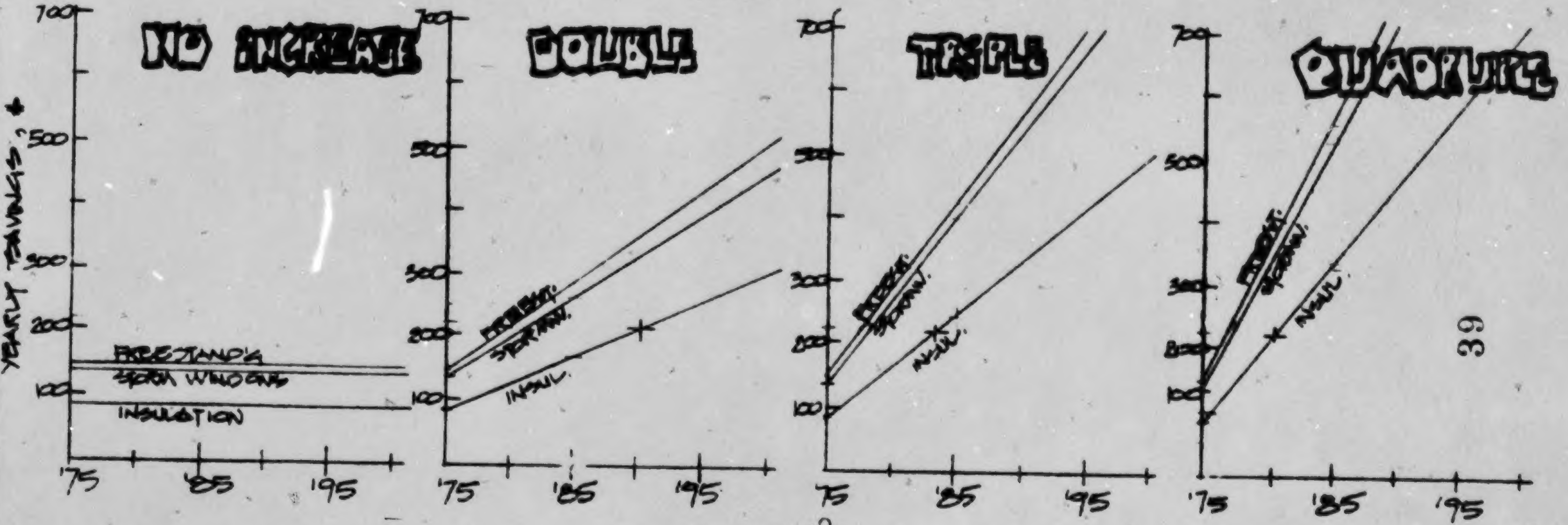


THE HILLS -8-

SAVINGS, COST, AND PAY-OFF

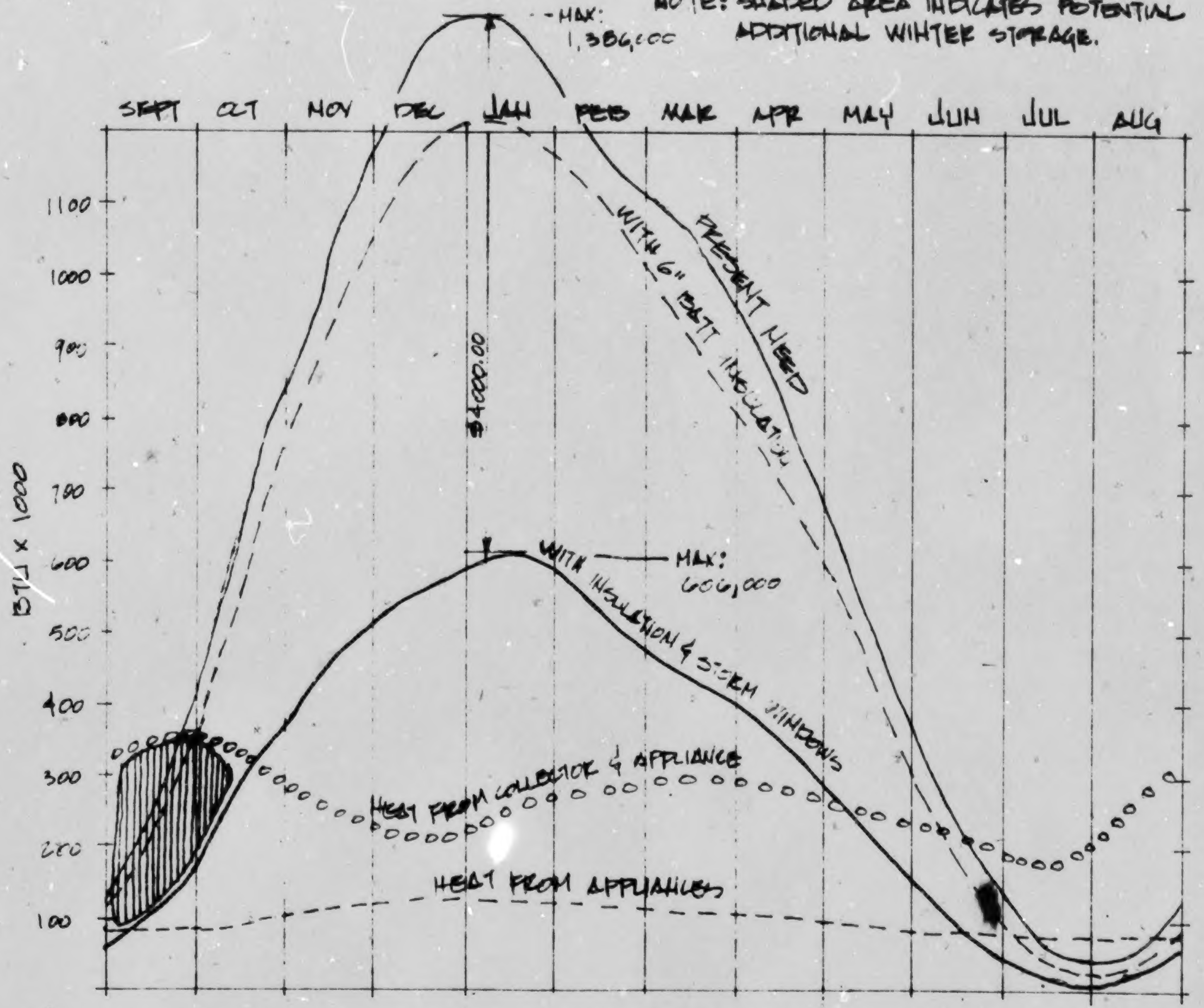
SOL MONTHS (OCT-MAY)	TOTAL KWH SPACE HEATING (CUMULATIVE)	TOTAL COST (BILLS) $ (@.013¢/KWH)	LABOR & MATERIAL COST $ (PER ITEM)			SAVINGS PER YEAR $ (PER ITEM)	APPROX. PAY-OFF IN YEARS FOR 10 YEAR RATE HIKES 0	 x2	 x3	
WHOLE HOUSE AS IT IS NOW	52,300	680								
ADD 6" FLOOR INSULATION	46,010	598	208			82	2½	2⅓	2	
AND STORM WINDOWS	35,850	466	3,960			132	30	15	10	
(GREENHOUSE W/ COLLECTOR	(~~WATER HEAT~~)	1,995	967							
(COLLECTOR ONLY))		814	401			40	21	10	7	
AND FREE STANDING COLLECTOR	25,100	326	8,284			140	59	29	17	

PAY-OFF POINT WITH VARIOUS RATE HIKES.

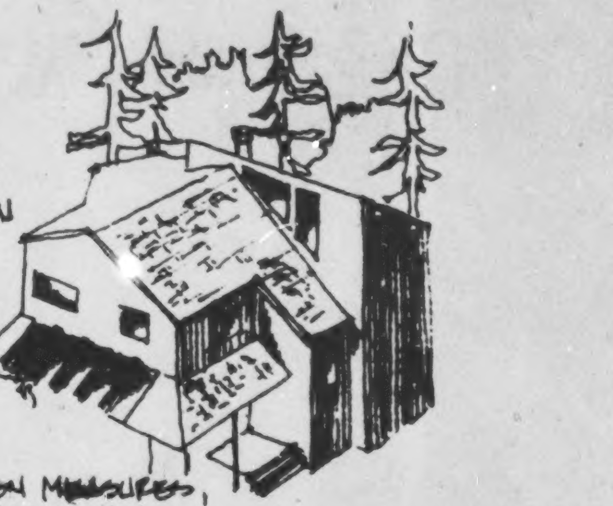


NEED AND SUPPLY

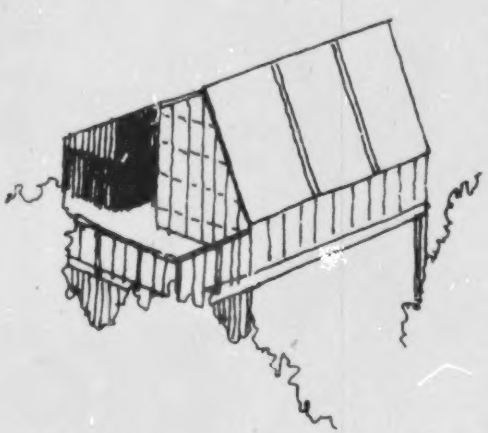
NOTE: SHADED AREA INDICATES POTENTIAL ADDITIONAL WINTER STORAGE.



PHASING



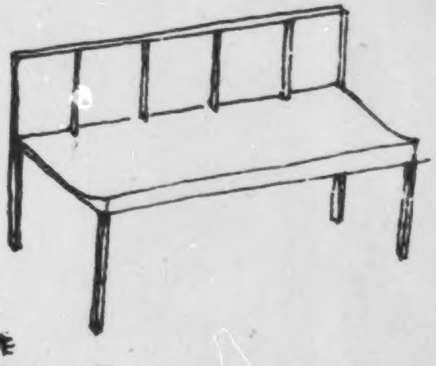
1 FLOOR INSULATION — FLOOR INSULATION WAS NOT INSTALLED WHEN THE HOUSE WAS BUILT. THE CRAWL SPACE ALLOWS EASY INSTALLATION TO A VERY EFFICIENT YET INEXPENSIVE MEANS OF SAVING HEAT. THE PRICE COMPARED TO HEAT SAVINGS, INDICATES THIS IS THE PLACE TO START.

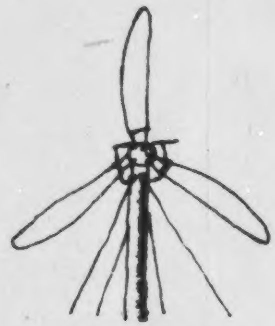


2 GREENHOUSE — THE HILLS INDICATED AN INTEREST IN A GREENHOUSE. IF THEY DECIDE TO SPEND THE MONEY THERE INSTEAD OF ON OTHER CONSERVATION MEASURES, A COLLECTOR FOR DOMESTIC HOT WATER CAN EASILY BE INTEGRATED

3 STORM WINDOWS — ALTHOUGH STORM WINDOWS ARE EXTREMELY EXPENSIVE, THEY ARE THE MOST LOGICAL APPROACH TO CONSERVATION. WITH LARGE ELECTRICAL RATE HIKES LOOMING IN THE NEAR FUTURE, THEY COULD EASILY BECOME THE MOST PRACTICAL OPTION.

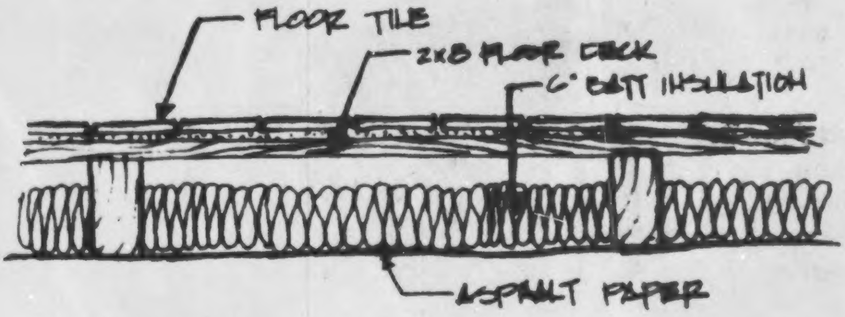
4 FREE STANDING COLLECTOR — TO SAVE THE ARCHITECTURAL INTEGRITY OF THE HOUSE, A FREE STANDING COLLECTOR IS AN OPTION TO SUPPLEMENT SPACE HEATING NEEDS. THE AREA UNDERNEATH CAN FURTHER BE USED FOR A CAR COVER OR STORAGE AREA. OF COURSE TO MAKE IT WORTH WHILE, ALL OTHER CONSERVATION OPTIONS SHOULD BE INSTALLED





5 WIND POWER — GENERATING ELECTRICITY FROM THE WIND IS POSSIBLE. (WE HAVE NOT DONE STUDIES ON THE POTENTIAL FOR THIS PARTICULAR SITE) IT IS HOWEVER "HIGH TECH," SOMEWHAT COMPLICATED, AND A LOT OF WORK. THIS SHOULD BE LEFT OPEN AS A FINAL OPTION SO THE POSSIBILITIES OF MASS PRODUCTION AND EASY INSTALLATION IN THE FUTURE MIGHT MAKE THINGS SIMPLER

1 FLOOR INSULATION


FLOOR TILE
2x8 FLOOR DECK
6" BATT INSULATION
ASPHALT PAPER

6" OF BATT INSULATION ADDED TO FLOOR

TILE AREA = 188 ft²
HARDWOOD = 380 ft²

DETERMINE NEW "R" VALUE

HDWD DECK = .45 ("R")
2x8 DECK = 2.50
6" BATT = 3.12x6 = 18.72
T = 21.67
U = .046

TILE = .04
2x8 DECK = 2.50
6" BATT = 18.72
T = 21.26
U = .047

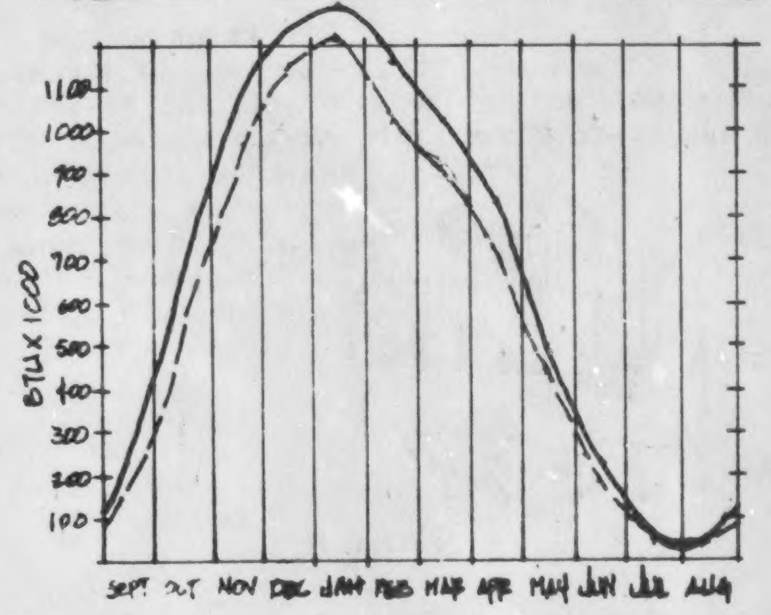
DETERMINE LOSS

HDWD = 380x.046x35 = 1300 BTUH
TILE = 188x.047x35 = 600 BTUH
T = 1900 BTUH

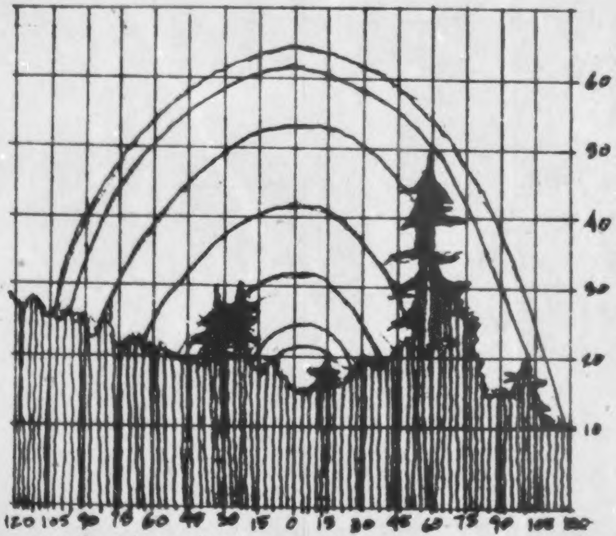
COST

MATERIALS	COST
6" BATT INSULATION 15¢ft²	180.00
6 BUNDLES 4' LATH 32¢	22.80
NAILS AND STAPLES	5.00
TOTAL	$207.80

NEED & SUPPLY CHANGE



2 GREEN HOUSE



SKYLINE CHART FROM ROOF OF CAR PORT

THE GREENHOUSE STARTED AS A BASIC SHED WITH SOUTH FACING GLASS AS IN FIG. A. THE COLLECTOR TO BE USED FOR DOMESTIC HOT WATER WAS ON THE BACK WALL WITHIN THE HOT HOUSE TO TAKE ADVANTAGE OF THE HEAT TRAPPED INSIDE. THE IDEA WAS OK BUT THE FORM WAS NOT. IN THE REDESIGN OF FIG. B, THE COLLECTOR-HOTHOUSE CONFIGURATION IS BASICALLY THE SAME WITH A LATH COVERED STAIR ADDED TO THE NORTH SIDE A SKYLIGHT REPLACING THE OUT DOOR DECK ON THE SOUTH. THIS SKYLIGHT ALLOWED THE CARPORT TO DOUBLE AS A HOTHOUSE ANNEX.

FURTHER INVESTIGATION REVEALED THAT CONDENSATION ON THE GLASS MIGHT BE A PROBLEM FOR THE COLLECTOR. IT WAS DECIDED TO MOVE THE COLLECTOR TO THE OUTSIDE OF THE GREENHOUSE. THIS WOULD ALLOW SOME PROTECTION FROM THE INTENSE SUMMER SUN FOR THE PLANTS INSIDE THE GREEN HOUSE (FIG. C). FINALLY THE SKYLIGHT ON THE SOUTH SIDE WAS SACRIFICED IN FAVOR OF A SMALL LATH HOUSE ON THE NORTH TO PROVIDE A WIND-SCREEN FOR AN OUT DOOR RELAXATION AREA (FIG. D.)

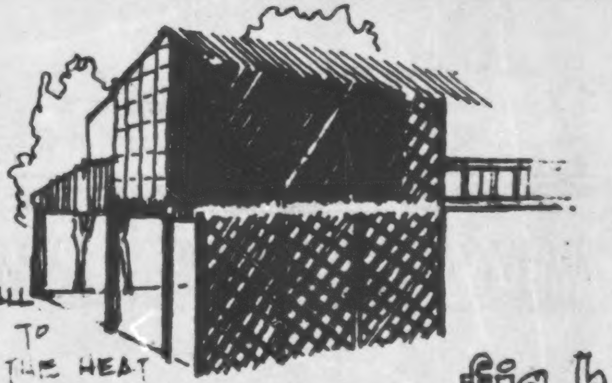


fig. b

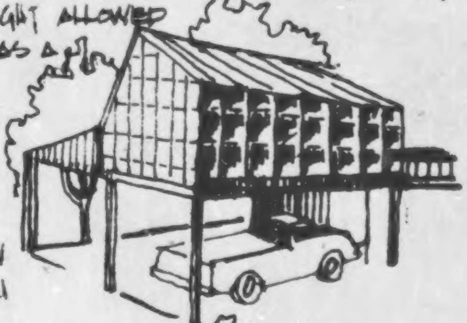


fig. c

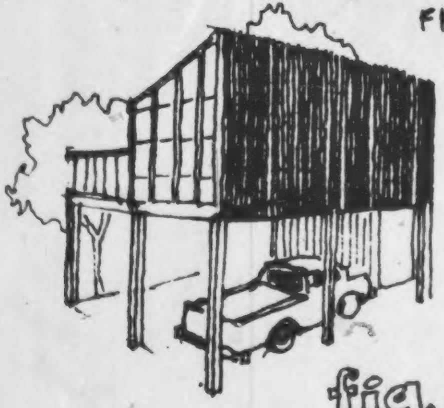


fig. a

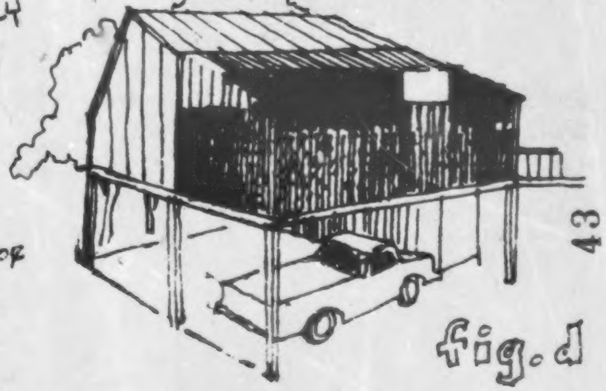
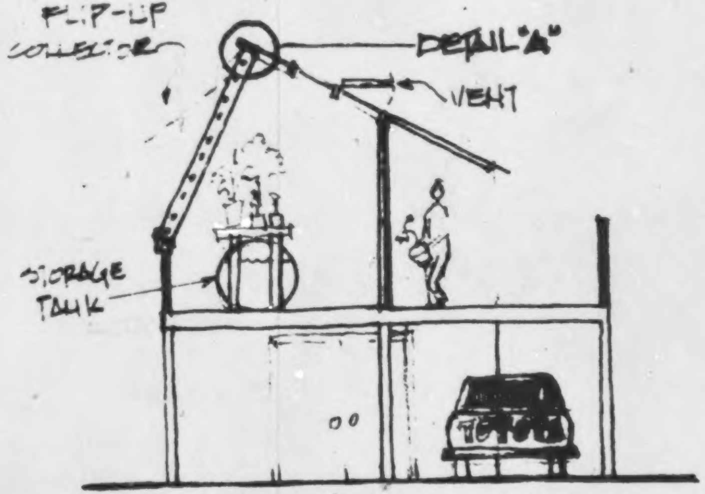
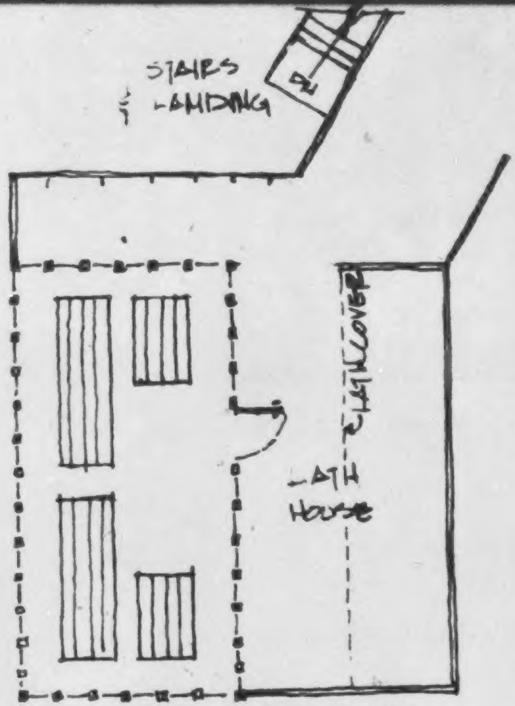


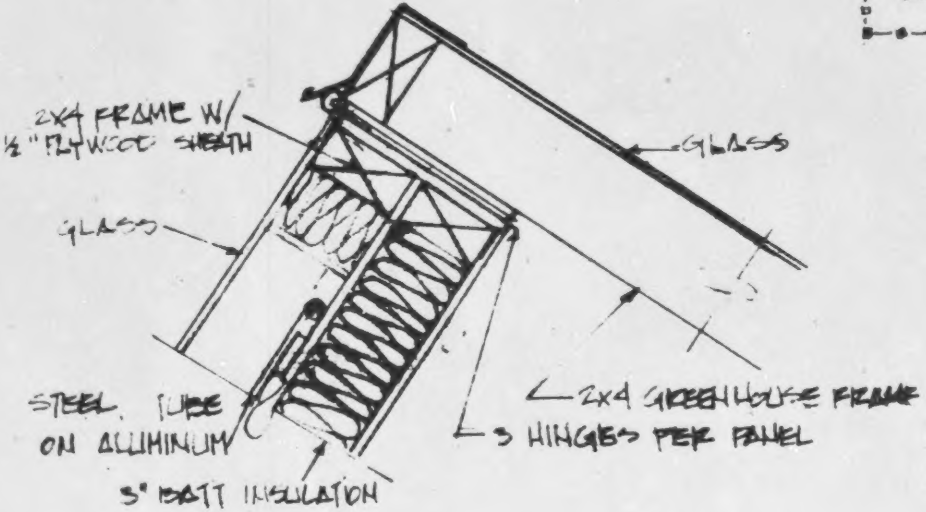
fig. d


FLIP-UP COLLECTOR
DETAIL "A"
VENT
STORAGE TANK

SECTION

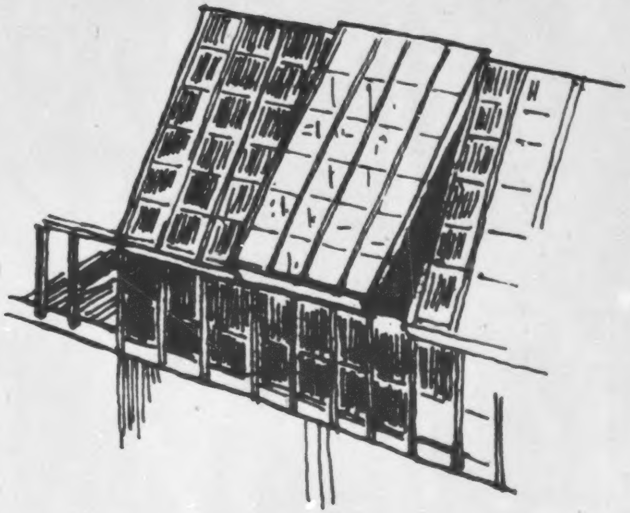

STAIRS & LANDING
LATH COVER
LATH HOUSE

UPPER FLOOR PLAN


2x4 FRAME W/ ½" PLYWOOD SHEATH
GLASS
GLASS
STEEL TUBE ON ALUMINUM
3" BATT INSULATION
2x4 GREENHOUSE FRAME
3 HINGES PER PANEL

DETAIL "A"

VIEW SHOWING FLIP-UP COLLECTOR PANEL



SIZING

THE SIZING FOR HOT WATER PRE HEAT IS BASED ON A Δt OF 90°F AND AN AVERAGE NEED OF 25 GALLONS OF WATER PER PERSON PER DAY

GAL/DAY × 8.33 lb/GAL × Δt = BTU/DAY

50 × 8.33 × 90 = 37,485

GOAL: 50% COLLECTION (WINTER)

$$\frac{(37,485 \text{ BTU/DAY})(50\%)}{680 \text{ AVG. WINT. DAY} \quad 33\% \text{ EFF.}} = 84 \text{ ft}^2$$

84 ft² OF COLLECTOR AREA NEEDED

COST

MATERIAL	COST $	INSTALLED
245 ft² GLASS	197.22	409.15
285 ft² LATH	39.90	73.81
930 ft² STUDS 16" O.C.	142.00	281.71
200 ft² INSUL.	22.00	50.00
200 ft² 26 GA. CORRUG. ALLUM.	56.00	106.00
400 ft² ½" PLYWOOD	69.00	115.20
6 20' 2×6s	15.60	26.05
10 HEAVY HINGES	30.00	45.00
84 ft² DBL PANE	135.	280.
84 ft² 2" DECKING	47.	84.40
250 ft ¾" PIPE	219.	450.
TOTAL	967.72	1995.33

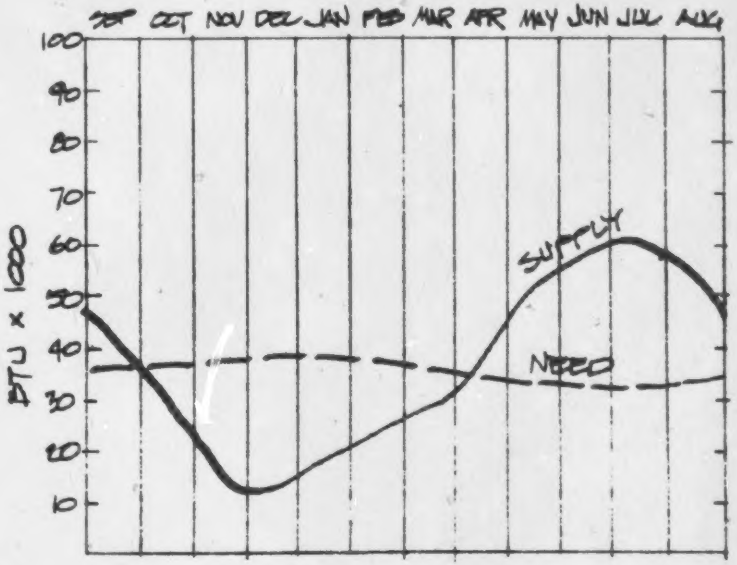
DETERMINING TANK SIZE

$$\frac{(1000 \text{ BTU/DAY})(84 \text{ ft}^2)(.33 \text{ EFF})}{(40° \Delta t)(8.33 \text{ lb/GAL})} = 83$$

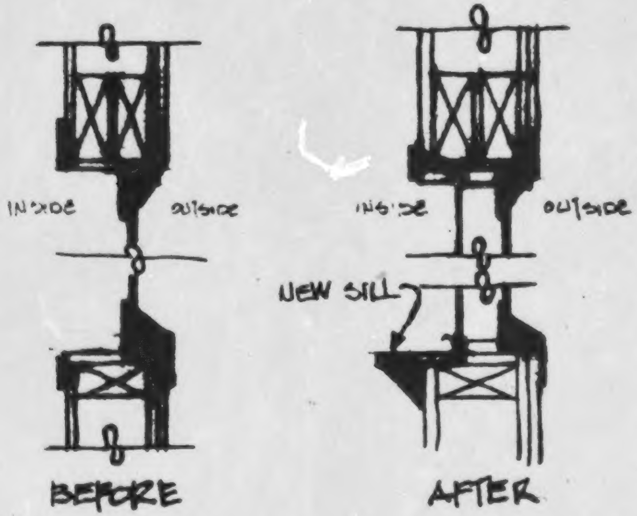
~83 GAL/DAY, USE 2-50 GAL SURPLUS DRUMS

THE HOT WATER PREHEAT IS DESIGNED ONLY TO RAISE THE WATER TO THE DESIRED TEMPERATURE. THE ORIGINAL HOT WATER HEATER WILL HOLD THE WATER AT THAT PRESCRIBED TEMPERATURE.

NEED vs. SUPPLY



3 STORM WINDOWS


INSIDE
OUTSIDE
INSIDE
OUTSIDE
NEW SILL
BEFORE
AFTER

GLASS AREA = 940 ft²
"U" FOR STORM WINDOWS = .56

940 x 50 x .56 = 26,400 BTUH

"U" FOR SKYLIGHT = .70
143 x 50 x .70 = 5000 BTUH

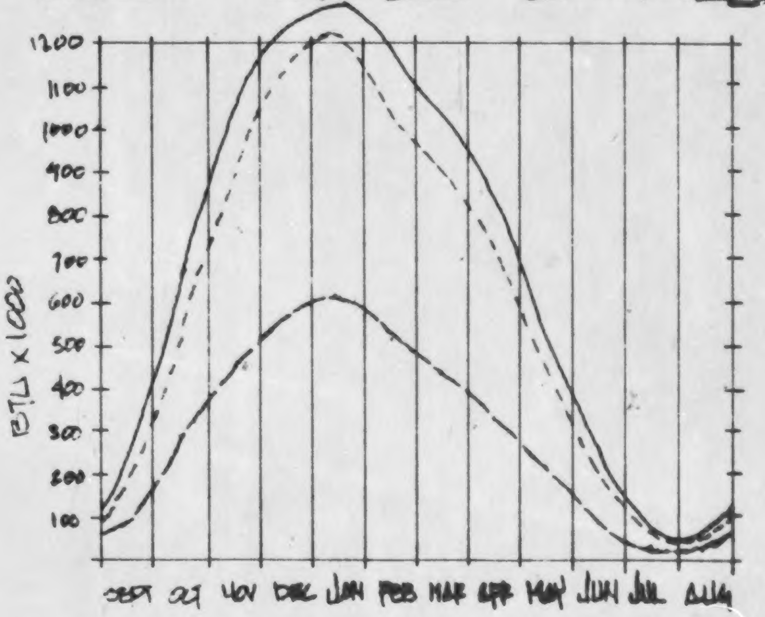
ADDING A SECOND PANE OF GLASS ALMOSTS CUTS IN HALF THE LOSS IN THIS HOUSE. ON THE FIXED PANE PORTION OF GLASS THE DETAIL CAN BE CARRIED OUT DISCREETLY AND WITH A MINIMUM OF EXPENSE.

BEWARE OF CONDENSATION.

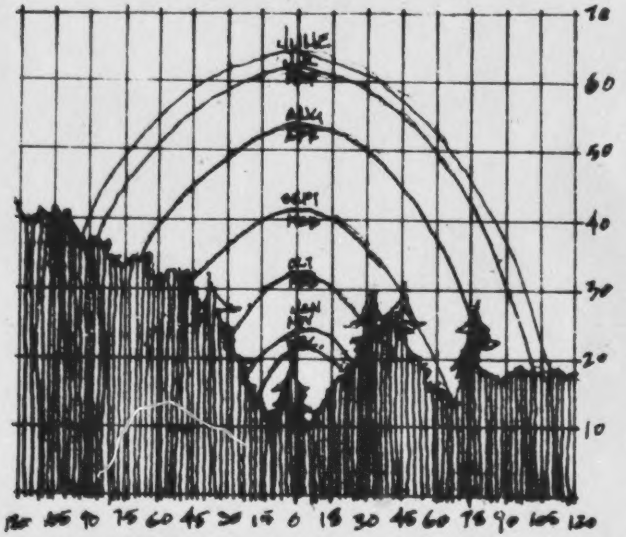
COST

MATERIAL	COST $
STORM WINDOWS	2314.05
NEW SUBFRAME SILL	653.00
LABOR	995.00
TOTAL	3962.05

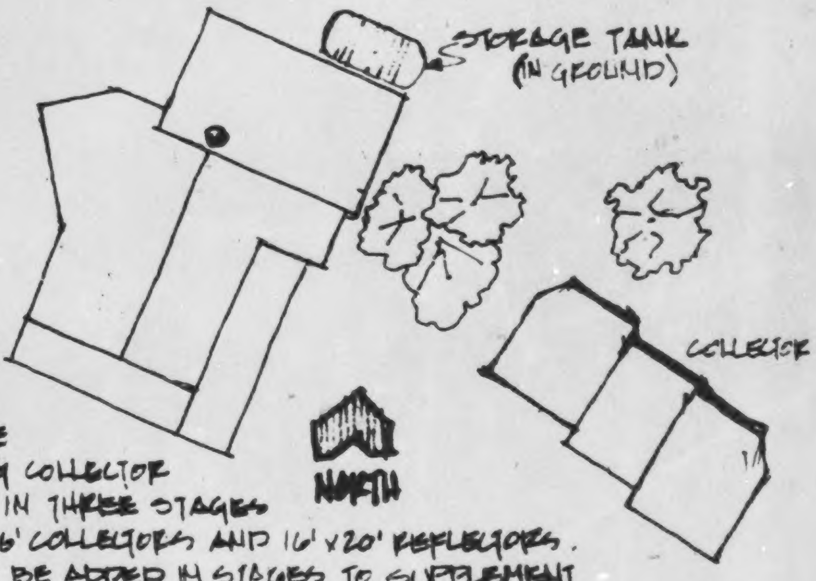
NEED & SUPPLY CHANGE



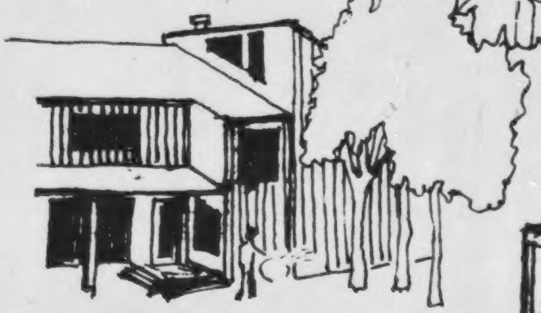
4 FREE STANDING COLLECTOR

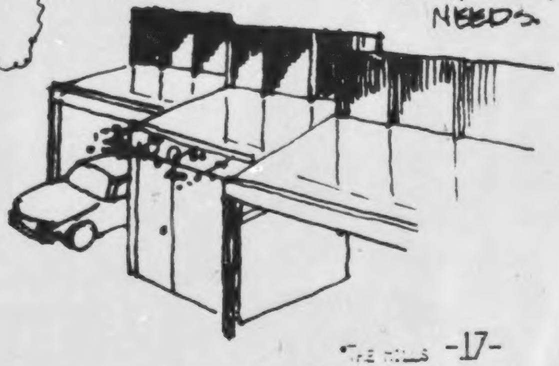


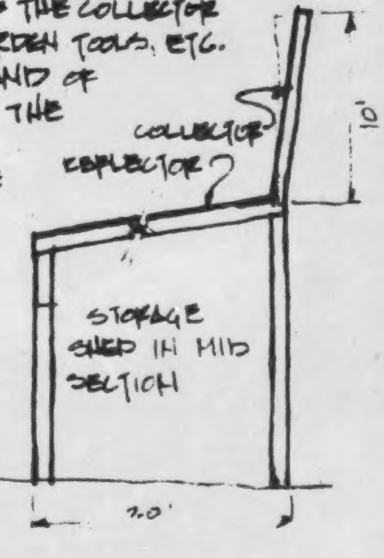
SUN CHART FROM FRONT DRIVE


STORAGE TANK
(IN GROUND)
COLLECTOR
NORTH

THE FREE STANDING COLLECTOR IS BUILT IN THREE STAGES OF 10'x16' COLLECTORS AND 16'x20' REFLECTORS. THEY CAN BE ADDED IN STAGES TO SUPPLEMENT THE NEEDS GRADUALLY AND TO MAKE PAYMENTS EASIER. THE UNDER PORTIONS OF THE COLLECTOR CAN BE USED FOR AN ADDITIONAL CARPORT OR EXTRA STORAGE SPACE FOR GARDEN TOOLS, ETC. A 3000 GALLON WATER STORAGE TANK CAN BE BURIED ON THE NORTH END OF THE HOUSE IN CLOSE PROXIMITY TO THE COLLECTOR TO SUPPLY ABOUT 3 DAYS OF STORAGE THIS COULD PROVIDE 30% OF HEATING NEEDS.






COLLECTOR
REFLECTOR
10'
STORAGE
SHED IN MID
SECTION
20'

SIZING

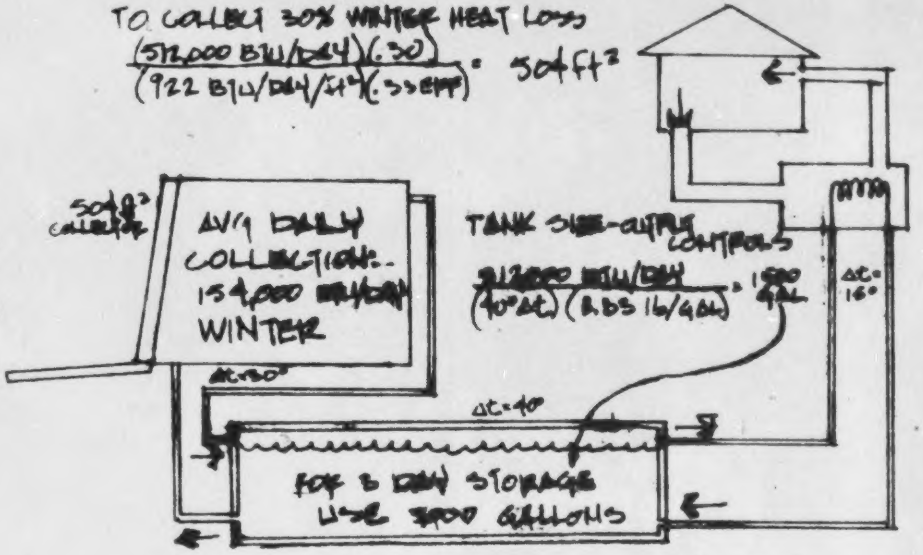
1) SKIN LOSS WITH STORM WINDOW & FLOOR INSULATION = 50,713 BTU/HR
2) LOSS PER HR. PER ft² (INCLUDES LONG LOSS = 25.7
3) BTU/DAY = 512000
APPROXIMATLY 50% REDUCTION OF ORIGINAL HEAT NEEDS

FOR SIZING OF COLLECTOR PLUS REFLECTOR USE A MULTIPLICATION FACTOR OF 1.5 BECAUSE OF REFLECTOR EFICIENCY.

∴ INSTEAD OF MAX. DAILY COLLECTION OF 615 BTU/DAY/ft² USE 615 x1.5 = 922 (FOR VERTICAL COLLECTOR)

TO COLLECT 30% WINTER HEAT LOSS

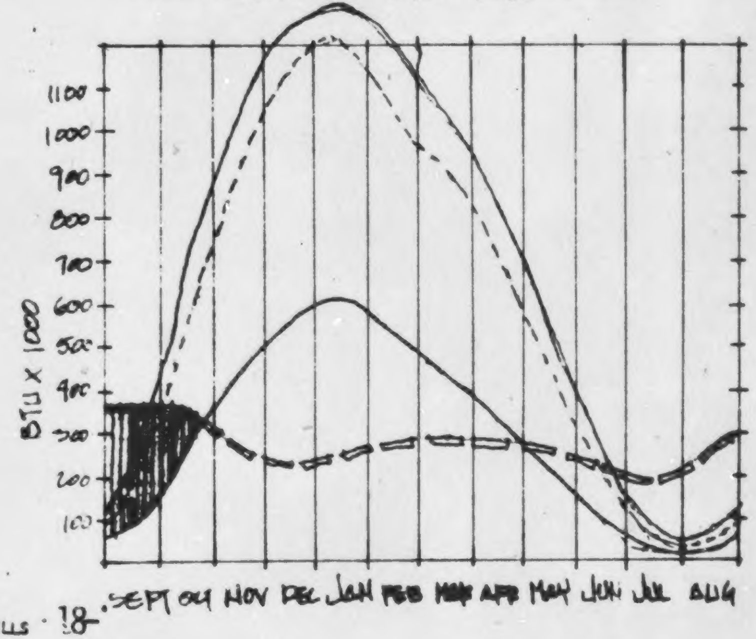
$$\frac{(512{,}000\ BTU/DAY)(.30)}{(922\ BTU/DAY/ft^2)(.33\ EFF)} = 504\ ft^2$$


504 ft² COLLECTOR
AVG DAILY COLLECTION: 154,000 BTU/DAY WINTER
Δt=30°
Δt=40°
TANK SIZE-OUTPUT CONTROLS
512000 BTU/DAY / (40°Δt)(8.33 lb/GAL) = 1500 GAL
Δt=16°
FOR 3 DAY STORAGE USE 3500 GALLONS

COST

MATERIAL	COST	INSTALLED
480 ft² GLASS	386.40	801.60
1056 ft² 2X4 STUD 16" OC	164.00	519.96
480 ft² INSULATION	52.80	120.00
480 ft² 26 GA CORRUG ALLUM	174.40	254.40
2116 ft² ½" PLYWOOD	667.00	1200.60
8 8' 4X4	43.00	77.40
11440 ft ¾" PIPE	1252.00	2520.00
160 ft² 2X6 16" OC.	215.00	390.00
TANK	1200.00	2000.00
PUMP	120.00	200.00
THERMOSTAT	240.00	100.00
TOTAL	4374.60	8283.96

SUPPLY vs. NEED



5 WIND POWER

IN AN EARLIER ENCOUNTER WITH THE HILLS, THE SUBJECT OF WINDPOWER CAME UP AS AN ALTERNATIVE POWER SOURCE. WE DID SOME RESEARCH IN THE AREA OF ELECTRICAL GENERATING WIND MACHINES, BUT IT TURNED OUT THEY SIMPLY WANTED TO USE ONE TO PUMP WATER FROM THEIR WELL AS IN FIG. A. WHILE IT IS CERTAINLY A USEFUL IDEA AND FEASIBLE, WE DID NOT DETERMINE HOW MUCH SAVINGS WOULD ACTUALLY OCCUR

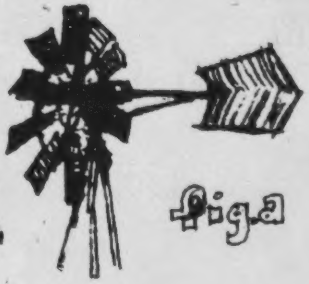


fig.a

WE DID LOOK INTO DIFFERENT TYPES OF WIND MACHINES. THE OLD 1930's JACOBS MODEL (FIG.B) CAN BE MODIFIED TO PRODUCE 144 KWH/MONTH. COMPARED TO THEIR LOWEST MONTHLY NEED OF ABOUT 1200 KWH, FEASABILITY IS QUESTIONABLE

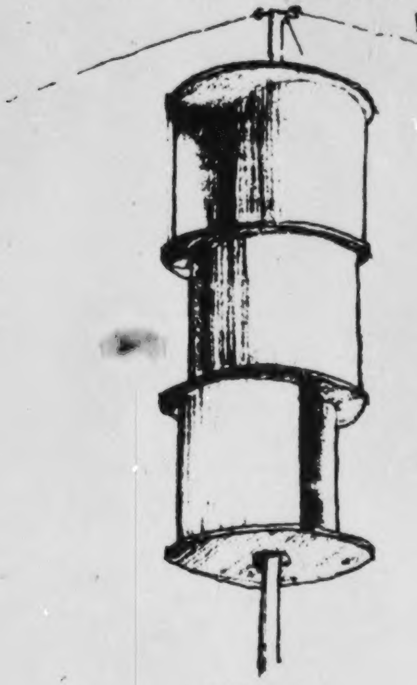


fig.c

A VERY INEXPENSIVE TYPE OF WIND MACHINE TO BUILD IS THE SAVONIUS/DARRIEUS TYPE SHOWN IN FIG.C. IT CONSISTS OF 3 SURPLUS OIL DRUMS CUT IN HALF LENGTH WISE AND ATTACHED TO PLYWOOD.

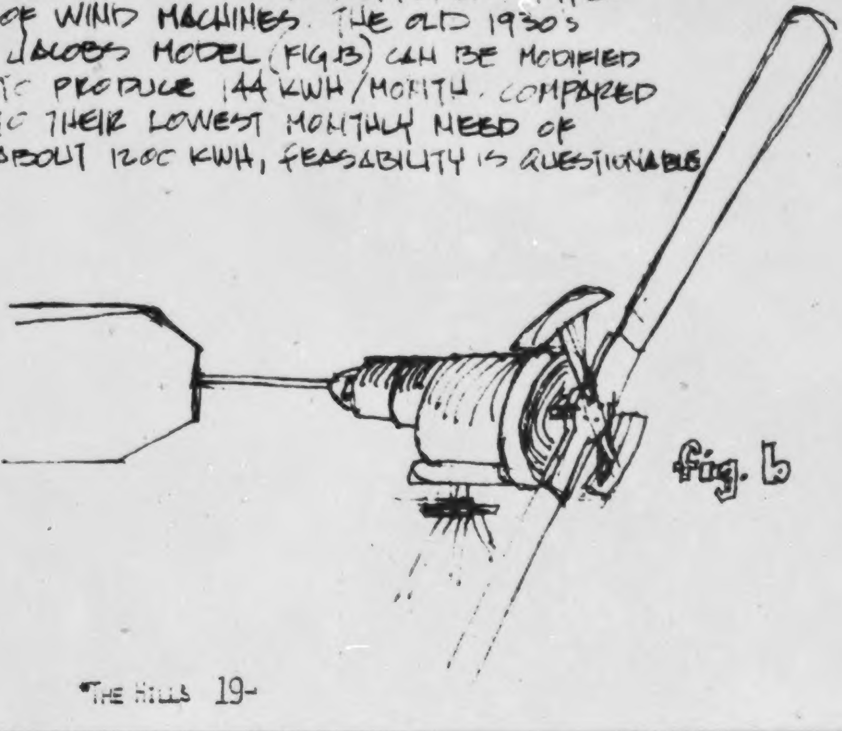
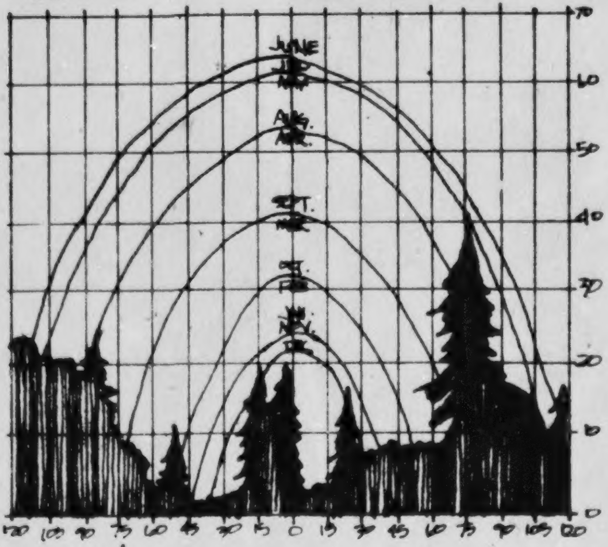
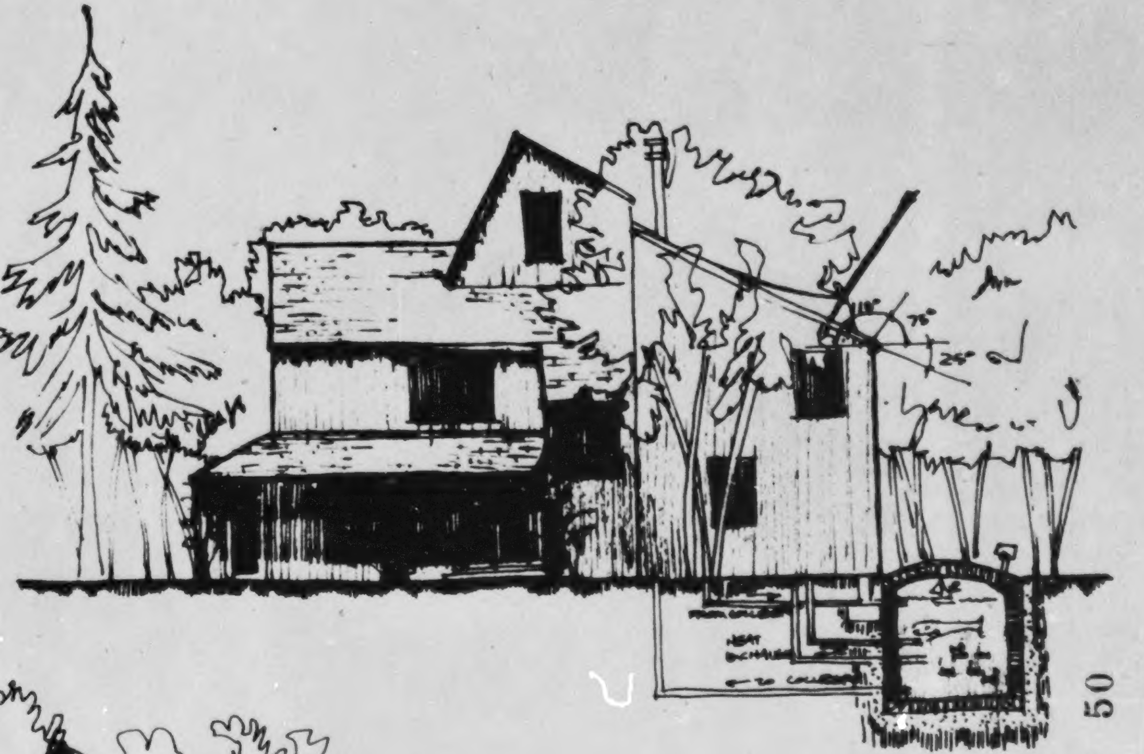
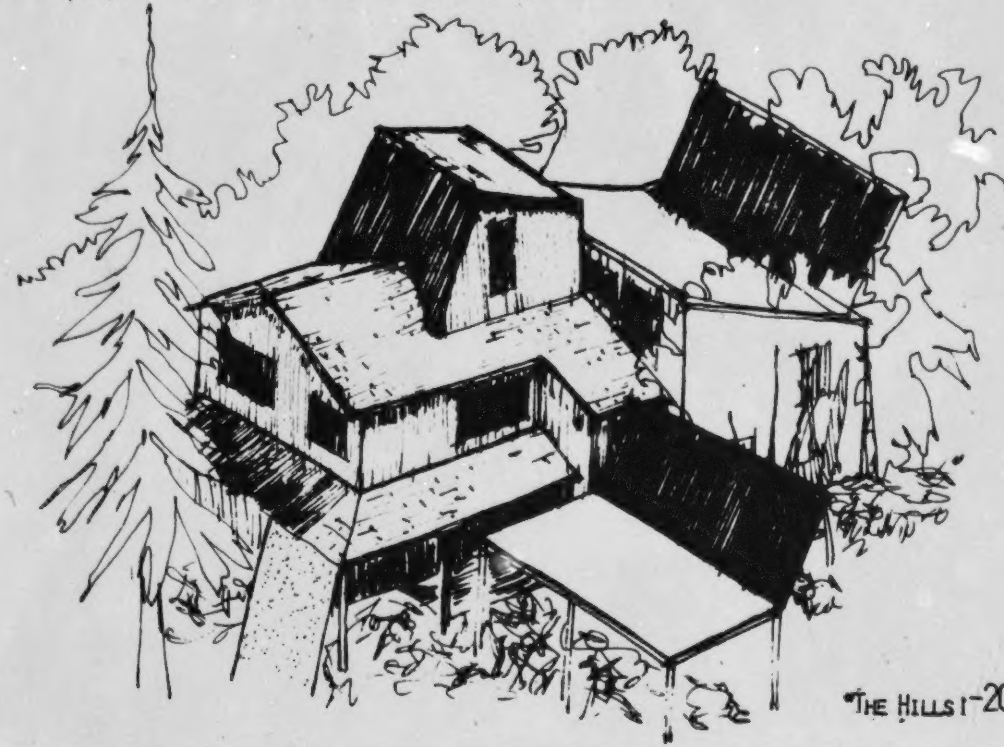


fig. b

CONSIDERATIONS







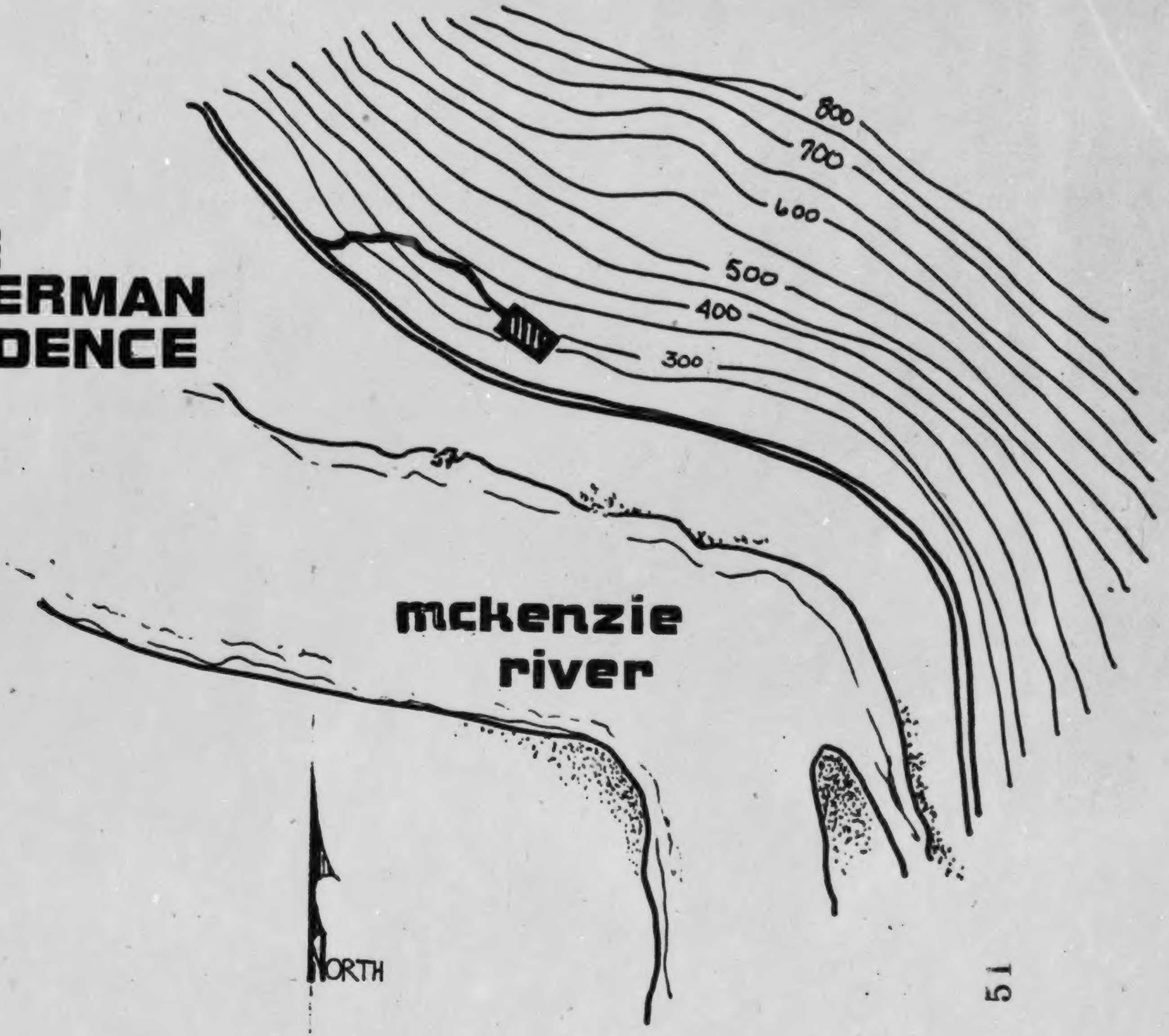
"THE HILLS"-20-

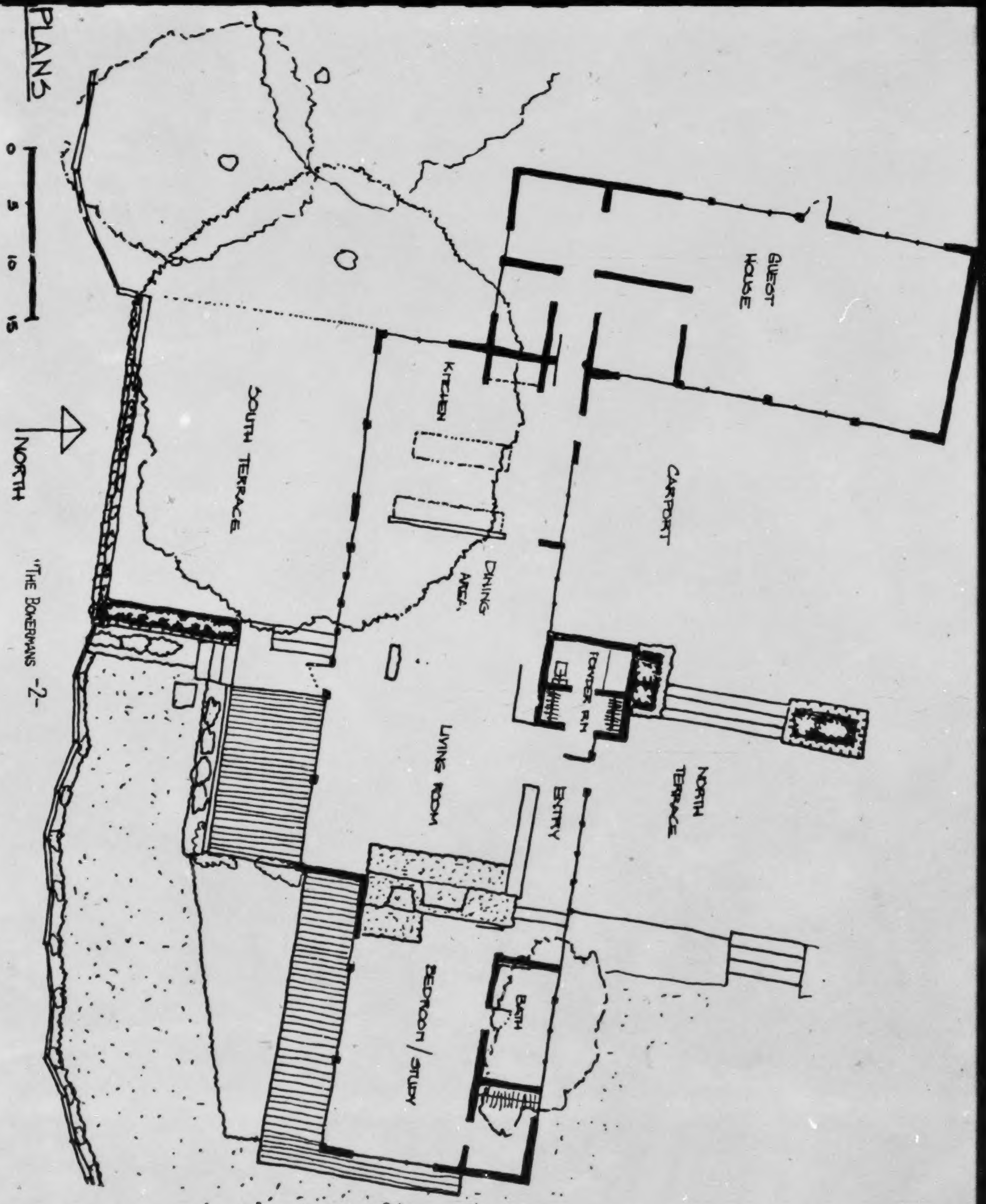
THE SUN CHART HERE SHOWS THE OPEN SKY FROM THE ROOF. OUR INITIAL RESPONSE WAS TO LOCATE THE COLLECTOR ON THE HOUSE, BUT WE FOUND THAT CHANGING THE APPEARANCE SO GREATLY WAS UNDESIRABLE.

IT IS IMPORTANT TO MAKE SOLAR COLLECTION BECOME A PART OF THE DAILY ROUTINE IN THE USERS LIVES. LIKE ANY ADDITION SOLAR COLLECTION MUST BE CAREFULLY THOUGHT THROUGH TO BECOME AN ENRICHMENT!

T.B. & S.K.

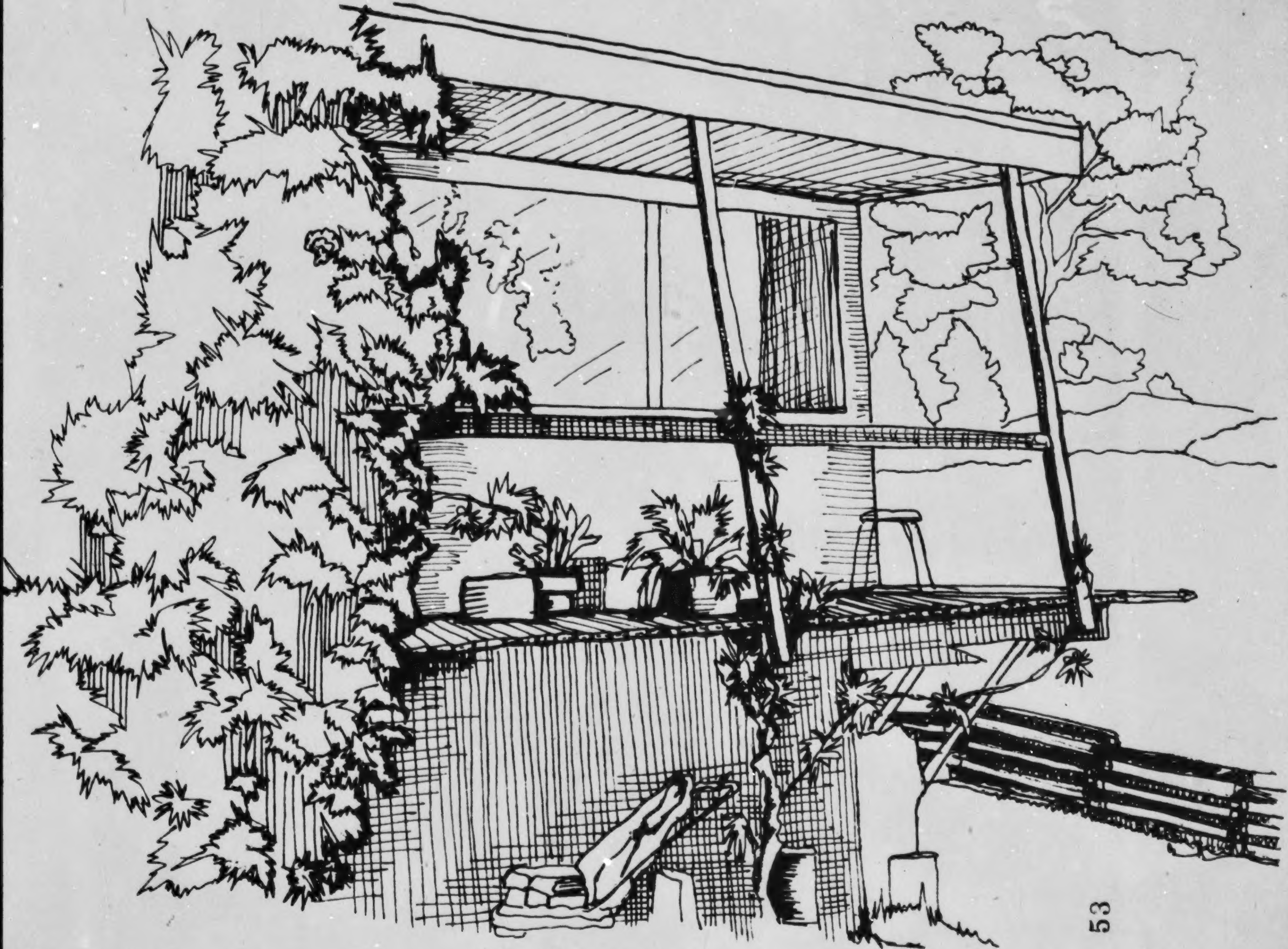
THE BOWERMAN RESIDENCE


800
700
600
500
400
300
mckenzie river
NORTH


PLANS

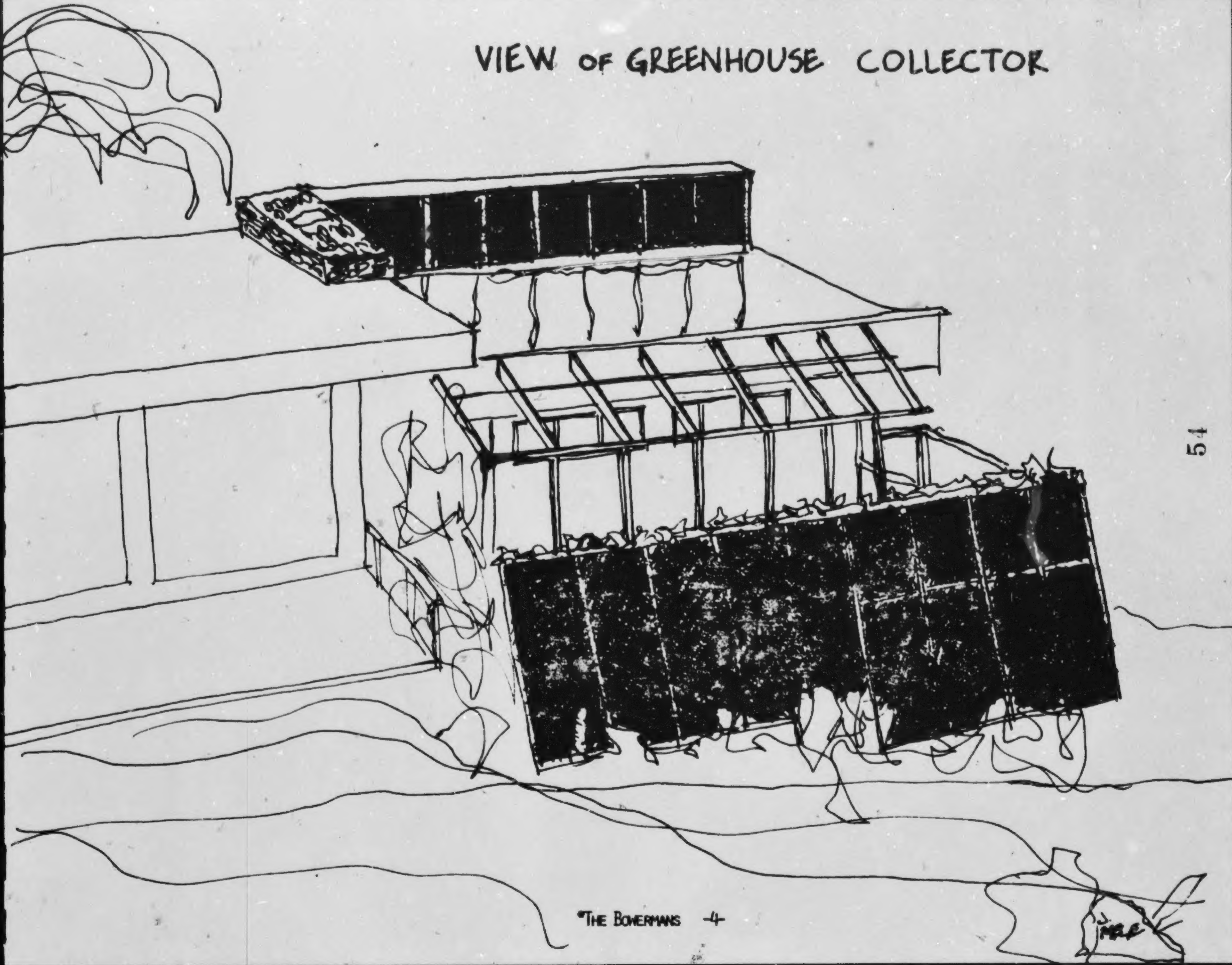
'THE BOWERMANS -2-

0
5
10
15
NORTH
GUEST HOUSE
KITCHEN
SOUTH TERRACE
CARPORT
DINING AREA
POWDER RM
NORTH TERRACE
LIVING ROOM
ENTRY
BATH
BEDROOM / STUDY



THE BOWERMANS -3-

VIEW OF GREENHOUSE COLLECTOR



©THE BOWERMANS -4-

BEDROOM HEAT LOSSES
PRESENT

TEMPERATURE CHANGE = 65° - 15° = 50°

WALLS.......	OUTSIDE AIR..............	.17
	STUCCO....................	.20
	3/8" PLYWOOD..............	.59
	3" FIBERGLASS INSUL......	1o.00 *
	GYPSUM LATH...............	.32
	1/2" PLASTER..............	.09
	INSIDE AIR................	.68
		12.09 = R
		1/R = U = .083

465 SQ. FT. x 50° x .083 = 1,929 BTU/HR

GLASS....... SINGLE PANE...U = 1.13
84 SQ. FT. x 50° x 1.13 = 4,746 BTU/HR

DOOR........HOLLOW CORE (1)...U= .43
14 SQ. FT. x 50° x .43 = 301 BTU/HR

FLOOR........	OUTSIDE AIR..............	.17
	2 x 4	3.28
	INSIDE AIR...............	-.92
		4.37 = R
		1/R = U = .229

444 SQ. FT. x 50° x .229 = 5,083 BTU/HR

ROOF.........	OUTSIDE AIR..............	.17
	5 PLY ROOF...............	.33
	2 x 4.....................	3.28
	INSIDE AIR...............	.92
		4.70 = R
		1/R = U = .228

444 SQ. FT. x 50° x .228 = 4,723 BTU/HR

INFILTRATION...VOLUME = 3,737 CU. FT.
3,737 x 1(AIR CHANGE/HR) x .018 x 50° = 3,363 BTU/HR

TOTAL BTU LOSSES FOR BEDROOM = 20,145 BTU/HR

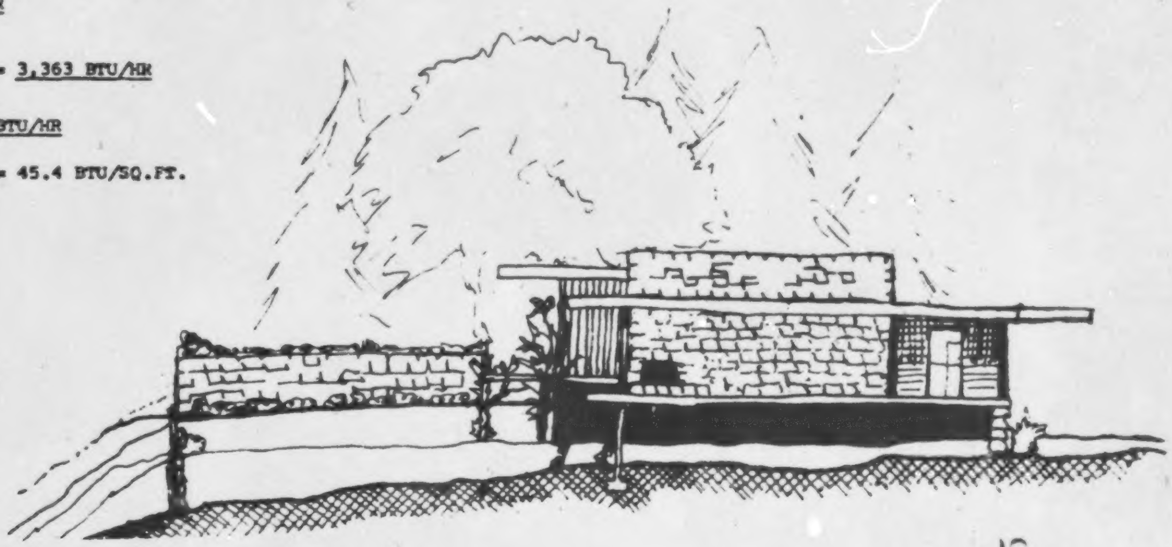
$$\frac{20,145}{444} = 45.4 \text{ BTU/SQ.FT.}$$

PRESENTLY THE BEDROOM IS NOT BEING USED DURING COLDER MONTHS BECAUSE OF THE COST OF HEATING IT. THIS ROOM HAS A MAGNIFICENT VIEW FROM THE McKENZIE RIVER BELOW AND STRETCHES COMPLETLY UNOBSTRUCTED TO THE SOUTH FOR ABOUT 30 MILES. THE BOWERMAN'S INSIST THAT ANY CHANGES TO THE HOUSE HAVE A MINIMAL IMPACT UPON THIS VIEW.

SINCE THE ENTIRE HOUSE IS BUILT DIRECTLY ON BEDROCK, IT WAS NECESSARY TO LOCATE A STORAGE TANK ABOVE GROUND. THE SPACE UNDERNEATH THE BEDROOM IS THE ONLY PLACE THAT IT COULD BE LOCATED WHERE IT COULD BE EASILY INSULATED AND UNSEEN, YET EASILY SERVICEABLE.

THE MAJOR HEAT LOSSES FROM THE BEDROOM ARE THROUGH THE CEILING AND FLOOR (NEITHER OF WHICH HAVE ANY INSULATION), AND THROUGH SINGLE PANE GLASS ON THE WINDOWS. THIS LACK OF ADEQUATE INSULATION AND THERMAL PANE SEEMS TO BE VERY WIDESPREAD IN HOUSES CONSTRUCTED DURING THIS TIME.

OTHER INFORMATION WHICH GREATLY AFFECTED OUR DECISIONS FOR RETROFITTING WERE THE FACTS THAT THE ROOF WAS 20 YEARS OLD AND WOULD SOON HAVE TO BE REPLACED, AND MS. BOWERMAN'S DESIRE FOR A GREENHOUSE IN THIS AREA. THEY WERE ALSO EXTREMELY HESITANT TO MAKE ANY CHANGES THAT WOULD ALTER THE BASIC LINES OF THE HOUSE, SUCH AS ADDING HEIGHT TO THE ROOF OR CHANGING MATERIALS.



*THE BOWERMANS -5-

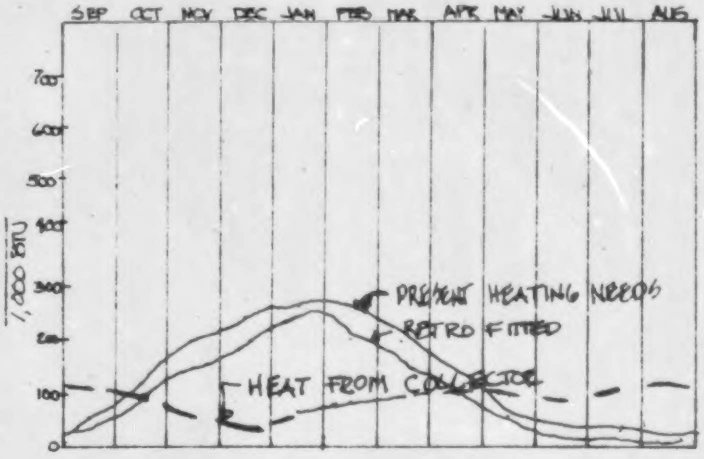
HEATING NEEDS---BEDROOM/GREENHOUSE

BTU LOSS PER DAY:

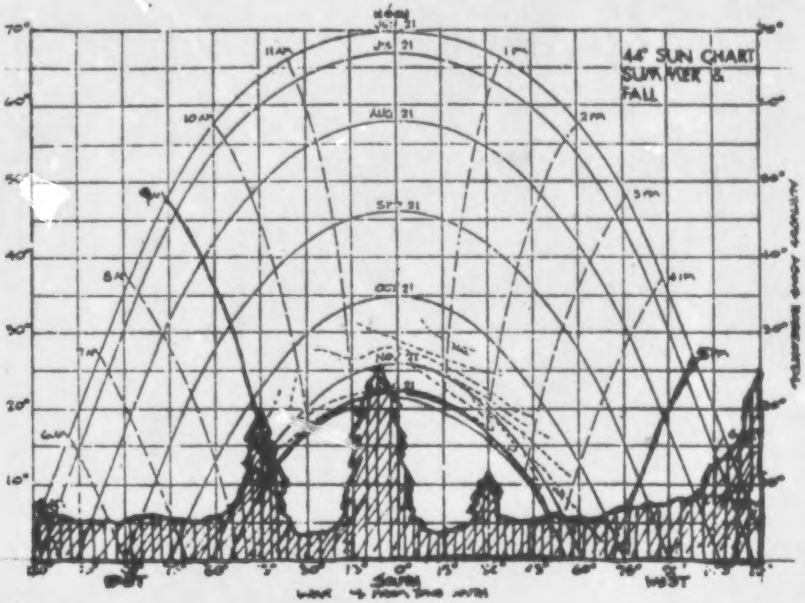
PRESENT- $\frac{\text{45.4 BTU/HR/SQ FT x 24 HRS}}{\text{65° BASE - 15° DESIGN}}$ = 21,8 BTU/SQ FT/DEGREE DAY

RETROFITTED- $\frac{\text{24.3 BTU/HR/SQ FT x 24 HRS}}{\text{65° BASE - 15° DESIGN}}$ = 11.7 BTU/SQ FT/DEGREE DAY

AVERAGE DEGREE DAYS			SPACE HEATING NEEDS/DAY				SOLAR ENERGY COLLECTED/DAY	
			"AS IS"		"RETROFITTED"		60° SOUTH FACING 33% EFF.	
MONTH	PER MO	PER DAY	X 21,8	X 444SQ FT	X11,7	X 642 SQ FT	/SQ FT	240 SQ FT
JAN	766	25	545	241,980	293	187,785	219	52,560
FEB	597	21	459	203,796	246	157,739	242	58,080
MAR	574	18.5	403	178,932	216	138,969	327	78,480
APRIL	456	15	327	145,188	175	112,671	352	84,480
MAY	289	9	196	87,024	105	67,603	403	96,720
JUNE	123	4	87	38,628	47	30,046	397	95,280
JULY	37	1	22	9,768	12	7,511	459	110,160
AUG	34	1	22	9,768	12	7,511	472	113,280
SEPT	119	4	87	38,628	47	30,046	492	118,080
OCT	366	12	262	116,328	148	90,137	367	88,080
NOV	580	19	414	183,816	222	142,717	204	48,960
DEC	729	23,5	512	227,328	275	176,518	132	31,680



BR. & GREENHOUSE



BEDROOM/GREENHOUSE LOSSES
RETROFITTED

TEMPERATURE CHANGE = 65° - 15° = 50°

WALLS.........1/R = U = .083
314 SQ.FT. x 50° x .083 = 1,303 BTU/HR

COLLECTOR WALL

OUTSIDE AIR...........	.17
3/16 GLASS...........	
3/4" AIR SPACE.......	.56
3/16" GLASS...........	
3/4" AIR SPACE........	
20 GUAGE STEEL.......	
6" FIBERGLASS INSUL..	27.30
3/8" PLY..............	.59
INSIDE AIR...........	.68
	29.30 = R
	1/R = U = .034

72 SQ.FT. x 50° x .034 = 122.4 BTU/HR
(ASSUME HALF-DAY HEAT LOSSES) = 61.2 BTU/HR

GLASS.........SINGLE PANE...U = 1.13
31.5 x 50o x .034 = 1,780 BTU/HR +1780

GREENHOUSE GLASS(THERMAL PANE)
230 SQ.FT. x 50° x .65= 7,475 BTU/HR -7475
SOUTH FACING GLASS GAIN
VERTICAL 3' x 22' = 66SQ.FT.
66 SQ.FT. X 16.1* x 88%= 935 BTU/HR + 935
15% SLOPE 6' x 22' = 132 SQ.FT.
132 SQ.FT. x 12.8* x 88%= 1,487 BTU/HR +1487
5053 BTU/HR

*"insolation on south facing surfaces" Corvallis, Ore.

DOOR.........HOLLOW CORE(1)....U = .43
14SQ.FT. x 50° x .43 = 301 BTU/HR

FLOOR........OUTSIDE AIR........... .17

2 x 4..................	3.28
3 1/2" FIBERGLASS.....	13.65* ADDED
3/8" PLYWOOD..........	.59
INSIDE AIR............	.92
	18.61 = R
	1/R = U = .054

444 SQ.FT. x 50° x .054 = 1,199 BTU/HR
GREENHOUSE FLOOR.... 9 x 22 = 198 SQ.FT.
ASSUME NO HEAT LOSS DUE TO LOCATION OF STORAGE TANK DIRECTLY UNDERNEATH.

BEDROOM ROOF.....OUTSIDE AIR.............. .17

3/4" PLYWOOD............	.93
5" FIBERGLASS(ROOF).....	17.64*ADDED
5 PLY ROOF..............	.33
2 x 4...................	3.28
INSIDE AIR..............	.92
	23.27 = R
	1/R = U = .043

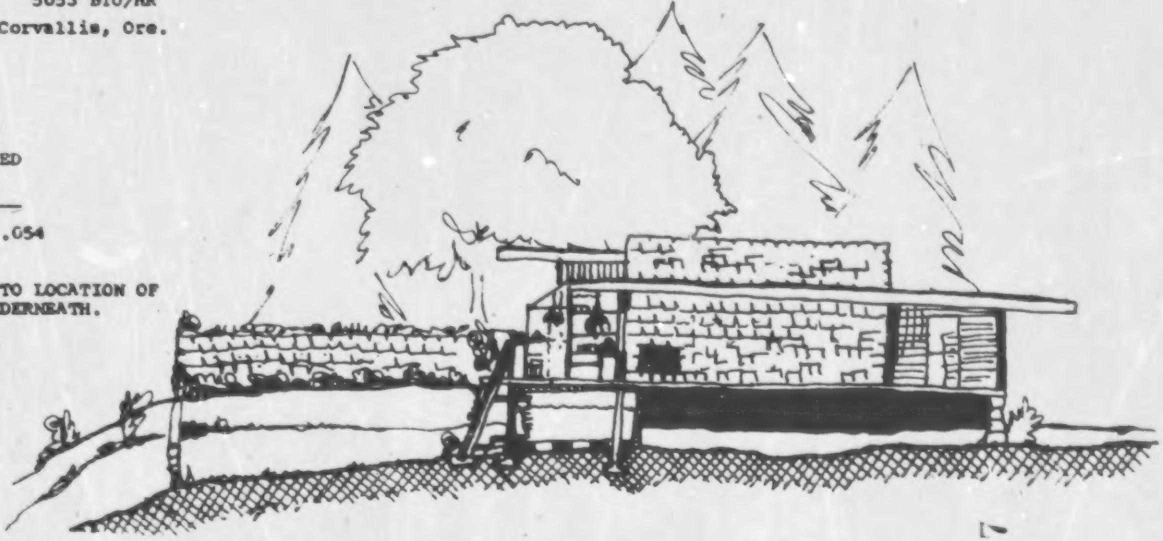
444 x 50° x .043 = 954 BTU/HR

GREENHOUSE ROOF..4 x 22 = 88 SQ.FT.
88 SQ.FT. x 50° x .043 = 189 BTU/HR

INFILTRATION.....BEDROOM....3737 CU.FT.
GREENHOUSE.1584 CU.FT.
5,321 CU.FT.
5,321 CU.FT..x.1$\left(\frac{\text{AIR CHANGE}}{\text{HOUR}}\right)$ x .018 x 50° = 4,789 BTU/HR

TOTAL BTU LOSSES FOR RETROFITTED BEDROOM GREENHOUSE
= 15,630 BTU/HR

FLOOR AREA 444 + 198 = 642 SQ.FT. $\frac{15,630}{643}$ = 24.3 BTU/HR/SQ.FT



SIZING FOR RETROFITTED BEDROOM/GREENHOUSE

THE BEDROOM/GREENHOUSE SYSTEM WOULD PROBABLY BE THE FIRST PHASE IN CONVERTING THE HOUSE TO SOLAR ENERGY, TAKING CARE OF PARTIAL SPACE HEATING FOR THIS AREA, AND HOT WATER NEEDS FOR THE HOUSE.

THIS IS THE PORTION OF THE HOUSE WHICH GETS THE COLDEST, AND IS ALSO A RELATIVELY SMALL ENCLOSED SPACE MAKING IT EASIER TO CONTAIN THE HEAT. THIS IS CONTRASTED WITH THE LIVING/DINING/KITCHEN AREA WHICH IS REALLY ONE LARGE ROOM.

SINCE WITH THE PRESENT ELECTRICAL HEATING SYSTEM THERE ARE NO DUCTS TO TAKE ADVANTAGE OF, HEATING THIS AREA WOULD REQUIRE A MINIMUM AMOUNT TO BE INSTALLED, ASSUMING THE STORAGE TANK TO BE PARTIALLY UNDER THE GREENHOUSE AND BEDROOM.

BY ADDING 66 SQUARE FEET OF GREENHOUSE WITH 230 SQUARE FEET OF THERMAL PANE, AND INSULATING BOTH THE ROOF AND FLOOR OF THE BEDROOM, THE BTU LOSS WOULD BE REDUCED FROM 45.4 BTU/SQ.FT. TO 24.3 BTU/SQ.FT.

INCLUDED IN THIS SCHEME WOULD BE A NARROW BEDDING AREA WHICH WOULD RUN THE LEGNTH OF THE TOP OF THE COLLECTOR, WHICH WOULD BE USED TO START VEGETABLES EARLIER IN THE SPRING. THIS WOULD ALSO UTILIZE THE SMALL AMOUNT OF HEAT LOSS THROUGH THE COLLECTOR TOP. UNDERNEATH THE DECK ON THE EAST SIDE WOULD BE AN AREA FOR STORING GARDEN TOOLS. A SPECIAL DUCT FROM THE TANK WOULD ALSO BE HERE, INCORPORATED INTO A FOOD DRYER, AND WOULD BE USED IN THE LATE SUMMER WHEN THERE IS AN EXCESS OF HEAT.

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (T)(Area)(U)= g 15,700 BTU/H

g 15,700 BTU/H ÷ 642 Floor Area= a 24.6 BTU/H/Ft^2

II. a (____Factor)(________Floor Area)= g ______BTU/H

'Conserving House' = 25 BTU/H/Ft^2

'Typical House' = 40 BTU/H/Ft^2

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (24.6 BTU/H/Ft^2)(24 Hr.) = b 11.8 BTU/Degree Day/Ft^2

(65° Inside Temp. - 15° Design Temp)

b (11.8 BTU/Degree Day/Ft^2)(642 Fl. Area)(21 Degree Days)= c 159,087 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

Insolation Data: (per Ft^2 of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft^2

Av. Winter Day = 670 BTU/Day/Ft^2

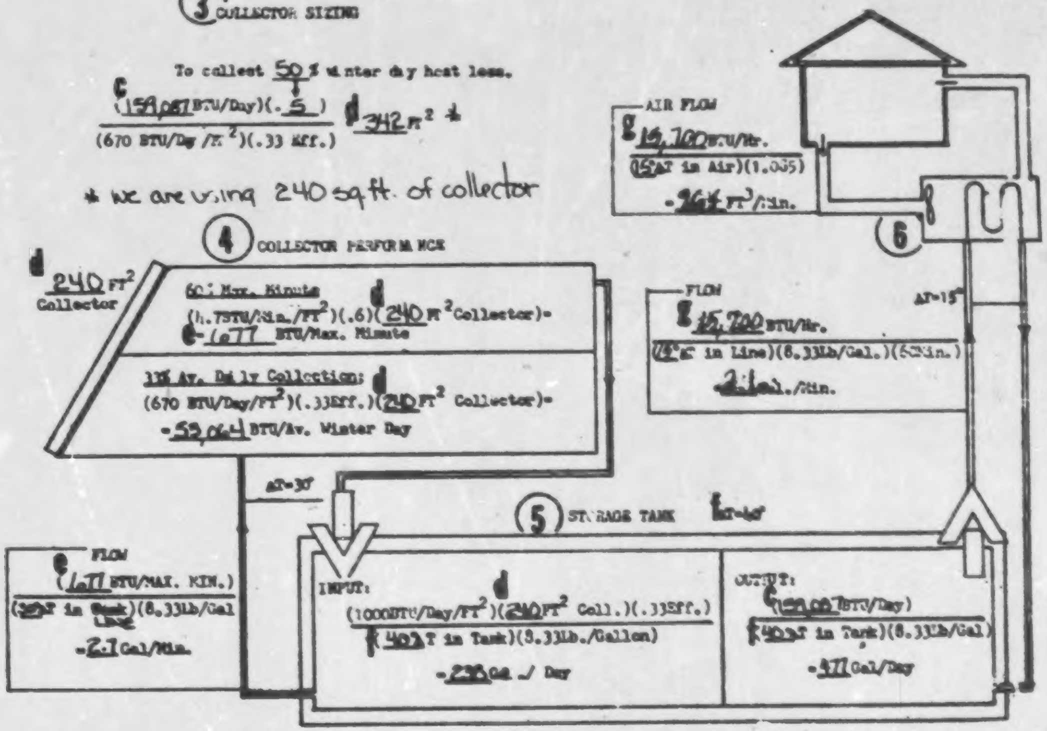
Max. Winter Day (100%)= 1000 BTU/Day/Ft^2

③ COLLECTOR SIZING

To collect 50% winter day heat loss.

$$\frac{c\ (159,087\ \text{BTU/Day})(.5)}{(670\ \text{BTU/Day/Ft}^2)(.33\ \text{Eff.})} = d\ 342\ \text{Ft}^2\ *$$

* we are using 240 sq.ft. of collector



④ COLLECTOR PERFORMANCE

d 240 FT^2 Collector

60% Max. Minute

(4.7 BTU/Min./FT^2)(.6)(d 240 Ft^2 Collector)= e 677 BTU/Max. Minute

33% Av. Daily Collection:

(670 BTU/Day/FT^2)(.33 Eff.)(d 240 Ft^2 Collector)= 53,064 BTU/Av. Winter Day

⑤ STORAGE TANK

FLOW

$$\frac{e\ (677\ \text{BTU/MAX. MIN.})}{(30° \text{T in Line})(8.33\text{Lb/Gal})} = 2.7\ \text{Gal/Min.}$$

INPUT:

$$\frac{d\ (1000\text{BTU/Day/FT}^2)(240\ \text{FT}^2\ \text{Coll.})(.33\text{Eff.})}{f\ (40° \text{T in Tank})(8.33\text{Lb./Gallon})} = 238\ \text{Gal./Day}$$

OUTPUT:

$$\frac{c\ (159,087\ \text{BTU/Day})}{f\ (40° \text{T in Tank})(8.33\text{Lb/Gal})} = 477\ \text{Gal/Day}$$

⑥ FLOW

$$\frac{g\ 15,700\ \text{BTU/Hr.}}{(15° \text{F in Line})(8.33\text{Lb/Gal.})(60\text{Min.})} = 2.1\ \text{Gal./Min.}$$

AIR FLOW

$$\frac{g\ 15,700\ \text{BTU/Hr.}}{(15° \text{T in Air})(1.085)} = 964\ \text{Ft}^3\text{/Min.}$$

TOTAL HOUSE HEAT LOSSES
PRESENT

THE SECOND PORTION OF OUR CALCULATIONS CONCERNED THE ADDITION OF A COLLECTOR/PARABOLIC REFLECTOR TO THE BEDROOM ROOF. USING THE HEAT GAINED FROM BOTH COLLECTORS, THE FOLLOWING EXPLORES THE POSSIBILITIES OF HEATING THE ENTIRE HOUSE WITH SOLAR ENERGY.

LIVING DINING AREA

```
WALLS..........OUTSIDE AIR..........  .17
               STUCCO...............  .20
               3/8" PLY.............  .59
               3" FIBERGLASS INSUL..10.00
               GYPSUM LATH..........  .32
               1/2" PLASTER.........  .09
               INSIDE AIR...........  .68
                                    12.09 = R
                                    1/R = U = .083
775 SQ.FT. x 50° x .083 = 3,216 BTU/HR
GLASS..........277 SQ.FT. x 50° x 1.13= 18,420 BTU/HR
    SOUTH FACING GLASS
               195 SQ.FT. x 16.1 x 88%=  2,763 BTU/HR
                                        15,657 BTU/HR
DOOR...........SOLID CORE(1)
               14 SQ.FT x 50° x .28 = 196 BTU/HR
               HOLLOW CORE(3)
               42 SQ.FT. x 50° x .43= 903 BTU/HR
                                     1099 BTU/HR
FLOOR-KITCHEN..OUTSIDE AIR..........  .17
               2 x 4................ 3.28
               LINOLEUM.............  .05
               INSIDE AIR...........  .92
                                     4.42 = R
                                     1/R =U = .226
469 SQ.FT. x 50° x .226 = 5300 BTU/HR
FLOOR-DINING/LIVING
               U = .326
603 SQ.FT. x 50° x .326 = 9,829 BTU/HR
ROOF...........OUTSIDE AIR..........  .17
               3 PLY BUILT..........  .33
               1/2" PLY.............  .49
               2 x 4................ 3.28
               6" INSULATION........24.00
               AIR SPACE............  .85
               3/8" GYPSUM BOARD....  .32
               INSIDE AIR...........  .61
                                    30.37 = R
                                    U = .033
1072 SQ.FT. x 50° x .033 = 1,715 BTU/HR
INFILTRATION...VOLUME = 8876 CU.FT.
8876 CU.FT. x 1AIR CHANGE) X 50° = 7,988 BTU/HR
                  HOUR
```

TOTAL BTU LOSSES FOR LIVING/DINING/KITCHEN AREA NOW 44,804 BTU/HR

$\frac{44,804}{1072}$ = 41.8 BTU/HR/SQ.FT.

TOTAL HEAT LOSSES FOR THE TOTAL HOUSE WITHOUT CHANGES...

```
20,145...BEDROOM
44,804...LIVING/DINING/KITCHEN
64,949...total
```

IMPROVEMENTS SUGGESTED FOR LIVING/DINING/KITCHEN AREA

1. ADD 3" INSULATION TO FLOOR OF DINING/LIVING ROOM ONLY (NOT ABLE TO INSULATE KITCHEN FLOOR)
   NEW U = .0813
   603SQ.FT. x 50° x .0813 = 2,451 BTU/HR
2. STORM WINDOWS
   277SQ.FT. x 50° x .56 = 7,756 BTU/HR

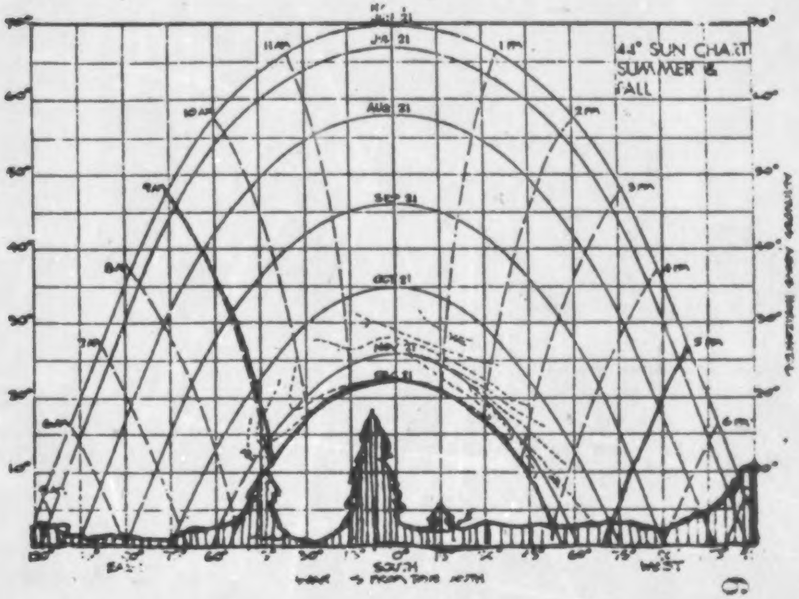
NEW BTU TOTAL = 29,165 btu/hr

$\frac{29,165}{1,072}$= 27.2 BTU/HR/SQ.FT.

TOTAL HEAT LOSS FOR THE TOTAL HOUSE WITH SUGGESTED IMPROVEMENTS

```
  29,165 BTU/HR
+ 15,630 BTU/HR
  44,795 BTU/HR
```

	AS IS	IMPROVED
BEDROOM	20,145 BTU/HR	15,630 BTU/HR
AREA	444 SQ.FT.	642 SQ.FT.
SQ.FT. BTU	45.4 BTU	24.3 BTU
TOTAL HOUSE	64,949 BTU/HR	44,795 BTU/HR
AREA	1518 SQ.FT.	1716 SQ.FT.
SQ.FT. BTU	42.8 BTU	26.1 BTU



SIZING DIAGRAM FOR HEATING THE WHOLE HOUSE
(Not including the guest room)

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (T)(Area)(U) g 44,795 BTU/H

g 44,795 BTU/H ÷ 1714 Floor Area = a 26.1 BTU/H/Ft²

II. a (___ Factor)(______ Floor Area) g ______ BTU/H

'Conserving House' = 25 BTU/H/Ft²
'Typical House' = 40 BTU/H/Ft²

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (26.1 BTU/H/Ft²)(24 Hr.) = b 12.5 BTU/Degree Day/Ft²

(65° Inside Temp. - 15° Design Temp)

b (12.5 BTU/Degree Day/Ft²)(1714 Fl. Area)(21 Degree Days) = c 450,932 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

* 450,932 - 130,000 = NEW C = 320,933

Insolation Data: (per Ft² of collector)

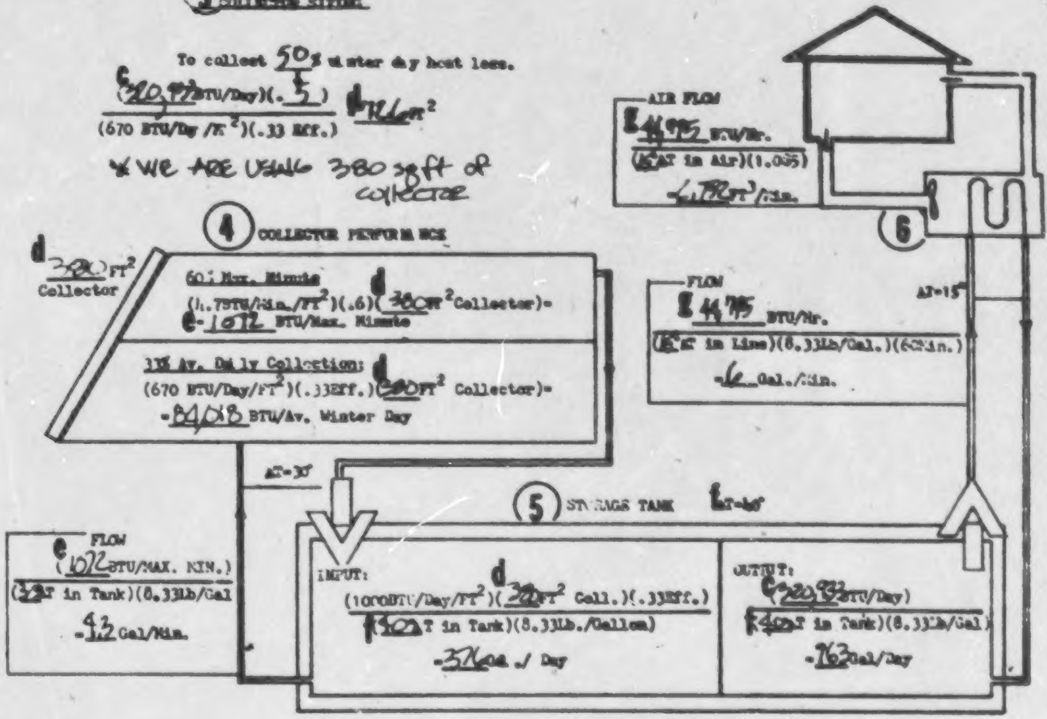
Max. Minute (100%) = 4.7 BTU/Min./Ft²
Av. Winter Day = 670 BTU/Day/Ft²
Max. Winter Day (100%) = 1000 BTU/Day/Ft²

③ COLLECTOR SIZING

To collect 50% winter day heat loss.

$$\frac{(c\ 320{,}932\ \text{BTU/Day})(.5)}{(670\ \text{BTU/Day/Ft}^2)(.33\ \text{Eff.})} = d\ 726\ \text{ft}^2$$

* WE ARE USING 380 sqft of collector


④ COLLECTOR PERFORMANCE
d 380 FT² Collector
60% Max. Minute
(4.7BTU/Min./FT²)(.6)(d 380 FT² Collector) =
e = 1072 BTU/Max. Minute
33% Av. Daily Collection:
(670 BTU/Day/FT²)(.33Eff.)(d 380 FT² Collector) =
= 84,018 BTU/Av. Winter Day
ΔT=30°
FLOW
e (1072 BTU/MAX. MIN.)
(32°T in Tank)(8.33lb/Gal
4.2
= 1.2 Gal/Min.
⑤ STORAGE TANK
f ΔT=40°
INPUT:
(1000BTU/Day/FT²)(d 380 FT² Coll.)(.33Eff.)
f(40°ΔT in Tank)(8.33Lb./Gallon)
= 376 Gal./Day
OUTPUT:
c (320,933 BTU/Day)
f(40°ΔT in Tank)(8.33Lb/Gal)
= 963 Gal/Day
AIR FLOW
g 44,795 BTU/Hr.
(35°ΔT in Air)(1.085)
= 1,180 FT³/Min.
⑥
FLOW
g 44,795 BTU/Hr.
(15°ΔT in Line)(8.33lb/Gal.)(60 Min.)
= 6 Gal./Min.
ΔT=15°

ACCORDING TO THE SIZING DIAGRAM ABOVE, THE COLLECTOR AREA IS ONLY 2/3 OF WHAT IS NEEDED TO SUPPLY 50% OF THE HEATING NEEDS FOR THE HOUSE.

HOWEVER, THESE AREN'T NECESSARILY THE NEEDS FOR THE BOWERMANS. SINCE THE BEDROOM IS NOT USED 24 HOURS A DAY, AND IS NEVER KEPT AS WARM AS THE REST OF THE HOUSE, THE NEEDS PER SQUARE FOOT ARE LOWER THAN ADVISED.

THE GREENHOUSE DOES NEED A MORE CONSTANT TEMPERATURE (60°-65°, DEPENDING UPON USE), YET ON SUNNY DAYS IT'S SOUTH FACING GLASS WILL PROVIDE PART OF THE HEATING. THIS WILL FREE SOME ENERGY FOR USE IN OTHER PARTS OF THE HOUSE. THE LOCATION OF THE STORAGE TANK AND COLLECTOR AS AN INTEGRAL PART OF THE GREENHOUSE WILL ALSO LESSEN HEATING DEMANDS.

FOR THESE REASONS, WE FEEL THAT 240 SQUARE FEET OF COLLECTOR WILL BE ADEQUATE TO HEAT THIS AREA.

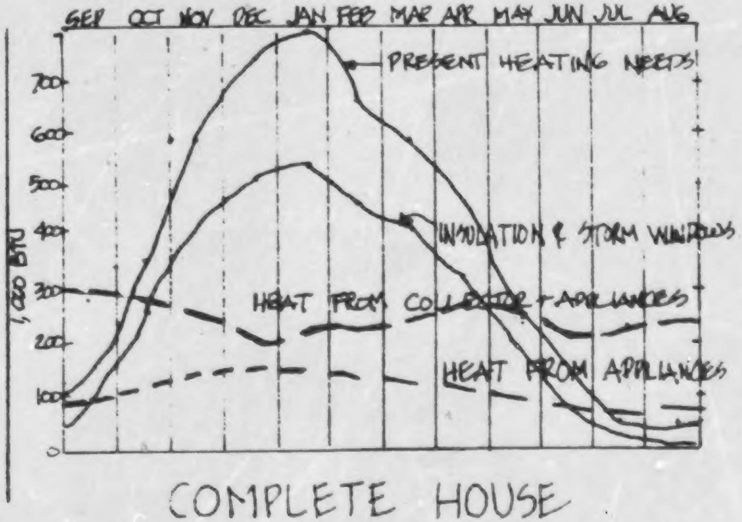
HEATING NEEDS-----COMPLETE HOUSE

BTU LOSS PER DAY:

PRESENT - $\frac{\text{42.8 BTU/HR/SQ.FT. x 24 HRS.}}{65^\circ\text{ BASE - }15^\circ\text{ DESIGN}}$ = 20.6 BTU/SQ.FT./DEGREE DAY

RETROFITTED - $\frac{\text{26.1 BTU/HR/SQ.FT. x 24 HRS.}}{65^\circ\text{ BASE - }15^\circ\text{ DESIGN}}$ = 12.5 BTU/SQ.FT./DEGREE DAY

AVERAGE DEGREE DAYS			SPACE HEATING NEEDS/DAY				SOLAR ENERGY COLLECTED/DAY	
			"AS IS"		"RETROFITTED"		60° SOUTH FACING 33% EFF.	
MONTH	PER MO.	PER DAY	X 20.6	X 1516SQ.FT.	X 12.5	X 1714SQ.FT.	/SQ.FT.	380 SQ.FT.
JAN	766	25	515	780,740	312.5	535,625	219	83,220
FEB	597	21	432.6	655,821	262.5	449,925	242	91,960
MAR	574	18.5	381.1	577,747	231	396,362	327	124,260
APRIL	456	15	309	468,444	187.5	321,375	352	133,760
MAY	289	9	184.4	281,066	112.5	192,825	403	153.140
JUNE	123	4	82.4	124,918	50	85,700	397	150,860
JULY	37	1	20.6	31,229	12.5	21,425	459	174,420
AUG	34	1	20.6	31,229	12.5	21,425	472	179,360
SEPT	119	4	82.4	124,918	50	85,700	492	186,960
OCT	366	12	247.2	374,755	150	257,100	367	139,460
NOV	580	19	391.4	593,362	237.5	407,075	204	77,520
DEC	729	23.5	484.1	733,896	293.8	503,487	132	50,160



COMPLETE HOUSE

*THE BOWERMANS -11-

COST ESTIMATE : PHASE 1 BEDROOM/GREENHOUSE

MATERIAL	AMOUNT	PRICE	LABOR	TOTAL
THERMOPANE GLASS	296 sq. ft. @ $7/ sq. ft.	$2072.00	included in est.	$2072.00
DIM LUMBER (2x4; 2x8 etc.)	900 BF @ 48¢/ BF	$432.00	$777.00	$1209.00
PLYWOOD (5/8"	420 sq. ft. @ 40¢/ sq. ft.	$168.00	$302.00	$470.00
FAN (for greenhouse)	1	$30.00	$30.00	$60.00
6" INSULATION	780 sq. ft. @ 13¢ sq. ft.	$101.00	$182.00	$283.00
MISC. (nails, etc.)		$50.00		$50.00
			TOTAL	$4,144.00

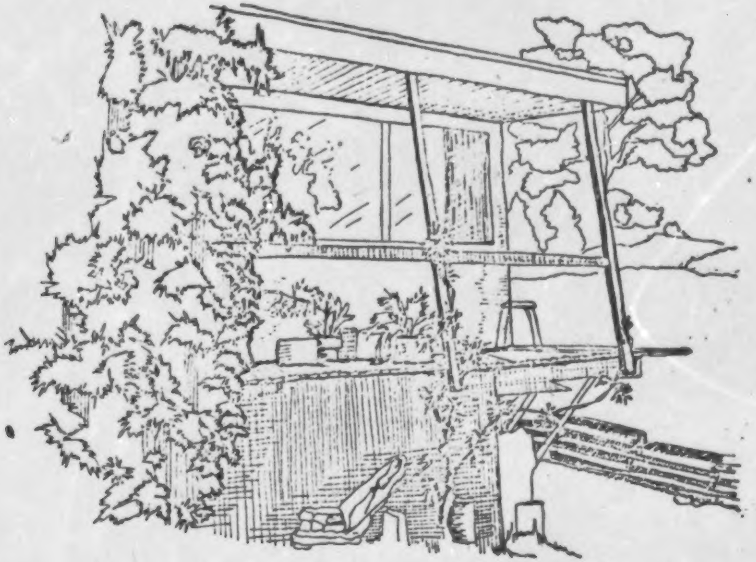
COST ESTIMATE: SOLAR COMPONENTS (labor not included)

MATERIAL	AMOUNT	PRICE
SOLAR COLLECTOR	240 sq. ft.	
	@ $4 sq. ft.	$960.00
	@ $7 sq. ft.	$1680.00
¼ hp MOTOR	1	$40.00
FURNACE	1	$160.00
STORAGE TANK	1000 gal.	
	fiberglass	$1000.00
	conc. septic tank	$250.00
	TOTAL LOW ESTIMATE	$1410.00
	TOTAL HIGH ESTIMATE	$2880.00

TOTAL ESTIMATE FOR PHASE 1 and 2 (approx.) $10,644.00

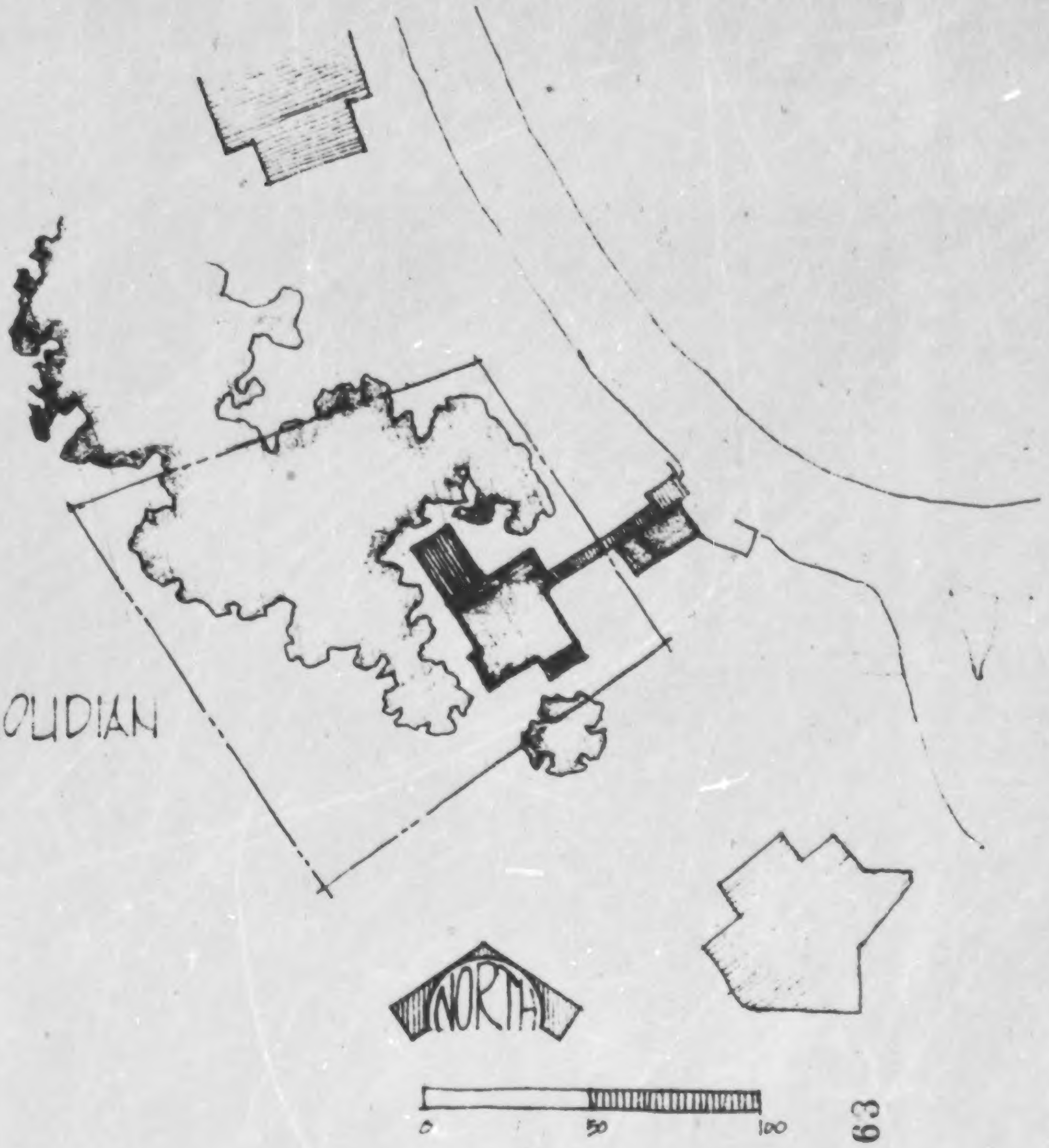
COST ESTIMATE: PHASE 2 ROOF COLLECTOR

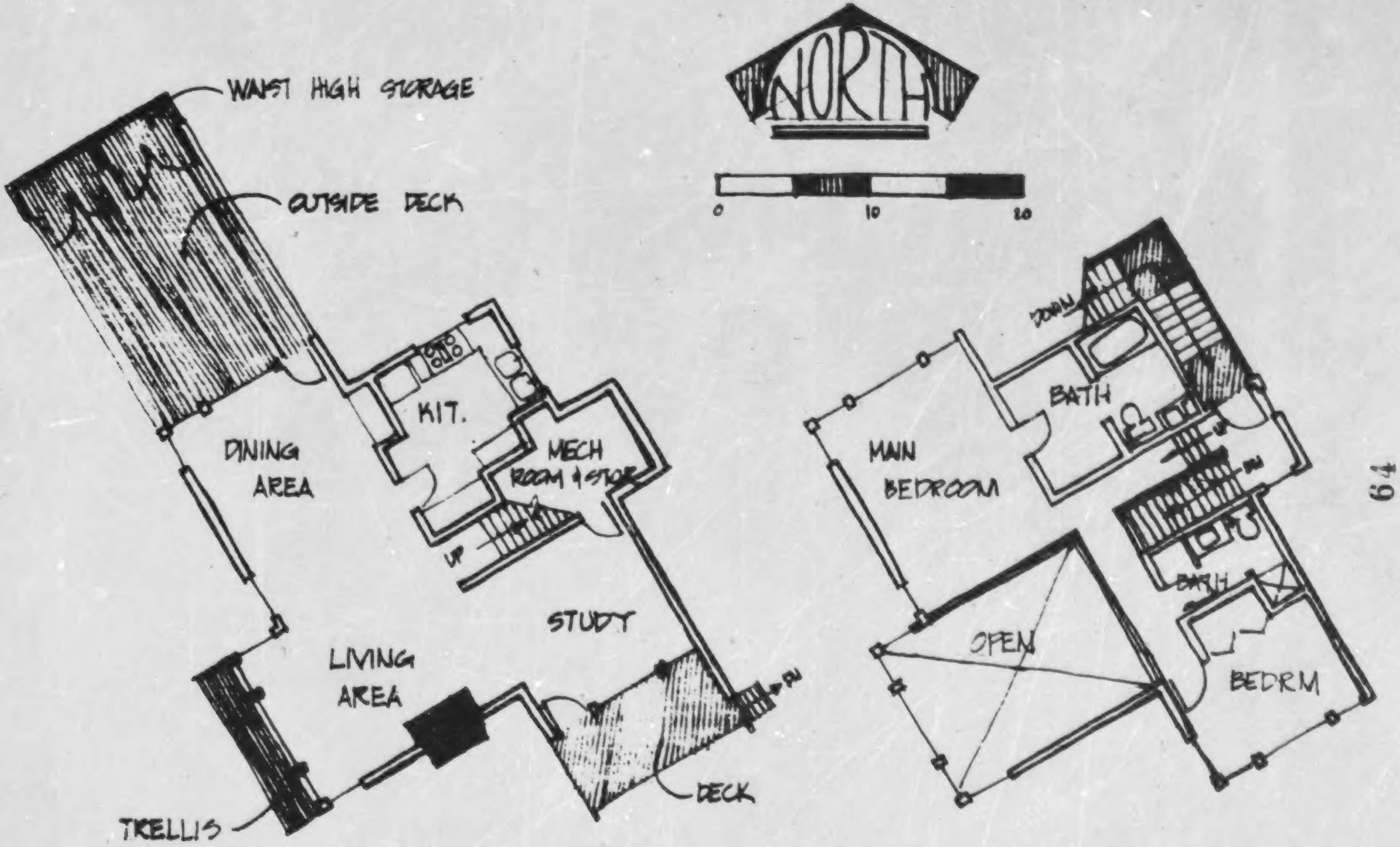
REPAIR AND REPLACE ROOF WITH PARABOLIC REFLECTOR	364 sq. ft.	@ $13 sq. ft.	$4732.00
COLLECTOR			
low estimate	140 sq. ft.	@ $4 sq. ft.	$560.00
high estimate	140 sq. ft.	@ $7 sq. ft.	$980.00
		APPROX. TOTAL	$5000.00



RESIDENCE

MISS KENAR CHARKOUDIAN


NORTH
0
50
100


NORTH
0
10
20
WAIST HIGH STORAGE
OUTSIDE DECK
DINING AREA
KIT.
MECH ROOM & STOR
UP
STUDY
LIVING AREA
DECK
TRELLIS
DN
DOWN
BATH
MAIN BEDROOM
UP
DN
BATH
OPEN
BEDRM

FIRST FLOOR

AREA 706 SQ FT.

UPPER FLOOR

AREA · 592 SQ FT.

©KAVAR CHAROODIAN -2-

HEAT LOSS

- FLOOR AREAS:

TOP 592 SQ FT
BOTTOM 706 SQ FT

TOTAL 1298 SQ FT

- RULE OF THUMB HEAT LOSS

40 BTUH (1298) = 51,920 BTUH

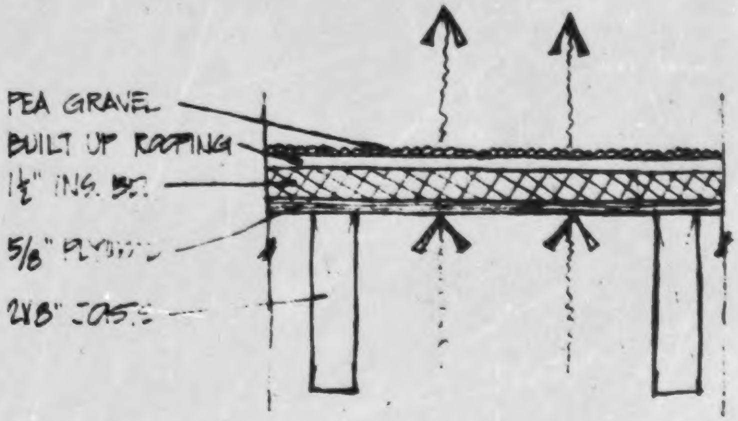
- BLDG SKIN LOSS

OUTSIDE TEMP	15°
INSIDE TEMP	65°
ΔT	50°

ROOF

OUTSIDE AIR FILM	.17
PEAGRAVEL	0
BUILT UP ROOF 3/8"	.33
1½" PRE FORMED INSULATION	4.17
5/8" PLYWOOD	.78
INSIDE AIR FILM	.68
	6.13

$\frac{1}{R} = \frac{1}{6.13} = .16$


PEA GRAVEL
BUILT UP ROOFING
1½" INS. BD.
5/8" PLYWOOD
2x8" JOISTS

772 SQ FT (50°)(.16) = 6176 BTU/H

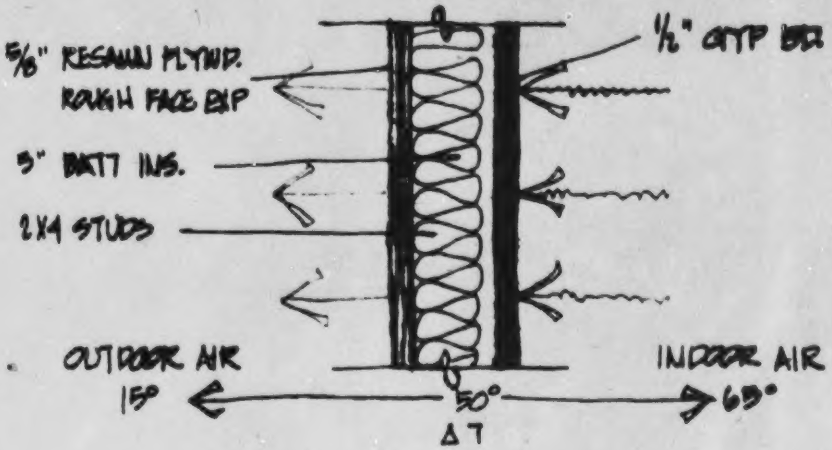
WALLS

	"R"
INSIDE AIR FILM	.68
½" GYP BD.	.45
3" BATT INSULATION	9.36
1" AIR SPACE	.96
5/8" PLYWD.	.78
OUTSIDE AIR FILM	.17
TOTAL	12.4

1/R = .08

TOTAL VERT EXTERIOR WALL SURF. 1100 SQ FT

LOSS = 1100 (50)(.08) = 4400 BTU/H

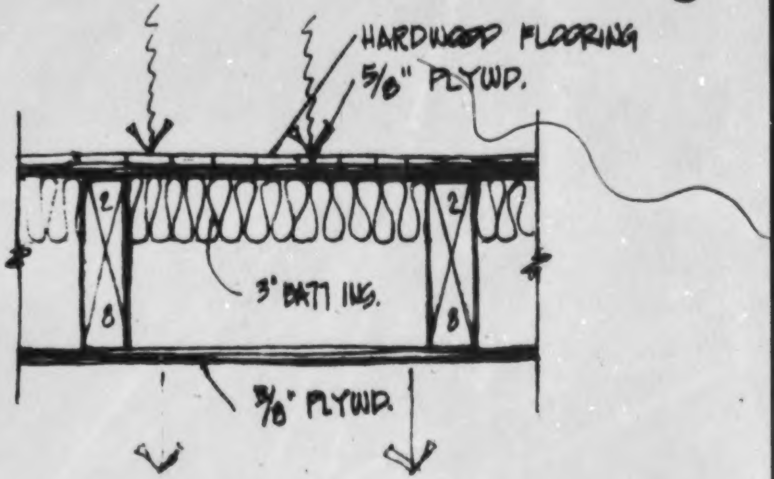

5/8" RESAWN PLYWD. ROUGH FACE EXP
3" BATT INS.
2X4 STUDS
½" GYP BD.
OUTDOOR AIR 15°
50° ΔT
INDOOR AIR 65°

FLOORS

FLOOR AREA 706 SQ FT.

INSIDE AIR FILM	.68
¾" HARDWOOD FLOOR	.68
5/8 PLYWD.	.78
3" BATT	9.36
5" AIR SPACE	1.08
5/8 PLYWD.	.78
OUTSIDE AIR FILM	.17
TOTAL	13.53

$\frac{1}{R}$ = .073


HARDWOOD FLOORING
5/8" PLYWD.
2
8
3" BATT INS.
5/8" PLYWD.

706 (50)(.073) = 2576 BTU/H

GLASS LOSSES

GLASS (FLAT - REGULAR)   U = 1.13

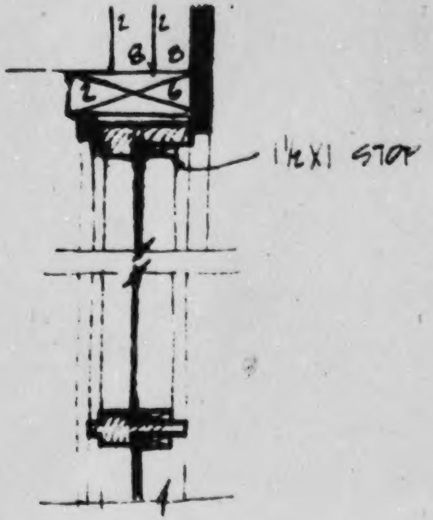
AREA = 750 SQ FT

750 (50)(1.13) = 42375 BTU/H

BATHROOM SKYLIGHT

12 SQ FT (50°)(1.15) = 690 BTU/H

PLASTIC 'U' 1.15



TYPICAL WINDOW DETAIL

TOTAL SKIN LOSS

ROOF	6176 BTU/H
WALLS	4400 BTU/H
VERT. GLASS	42375 BTU/H
SKYLIGHT	690 BTU/H
FLOORS	2576 BTU/H
	56217 BTU/H

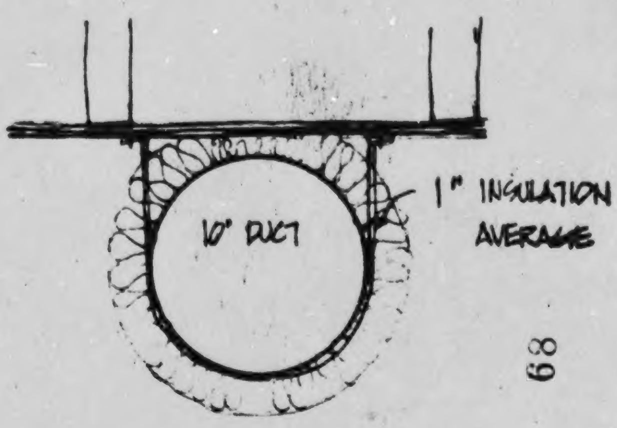
56217 BTU/H / 1298 SQ FT = 44 BTU/H/SQ FT SKIN LOSSES

LUNG LOSSES

VOLUMN 706 SQ FT X 20 FT = 14,120 CU.FT.

1 AIR EXCHANGE / HR. $\frac{14{,}120\,(50°)(.018)}{1298}$ = 9.7 BTU/H / SQ FT.

HEAT LOSS FROM EXPOSED DUCTS



OUTSIDE AIR FILM	.17
1" INSULATION	4.55
INSIDE AIR MOVING	.17
METAL DUCT	0

ER = 4.89 $\frac{1}{ER}$ = .20

INSIDE AIR TEMP 95° − 15° ΔT = 80°

AREAS BASED UPON APPROX 85' OF DUCT WORK

CIRC. = π (10") = 3.14 (10") = 31.4 " (12") = 376.8 SQ IN / FT OF LENGTH

85' (376.8) = 32028 SQ IN / 144 = 222 SQ FT

LOSS = .20 (222 SQ FT) (80°) = $\frac{3552}{1298 \text{ SQ FT}}$ BTU/H = 2.7 BTU/H / SQ FT

HEAT LOSS TOTALS

SKIN LOSSES	44 BTU/H/SQ FT.
INFILTRATION	9.1 BTU/H/SQ FT
DUCTS	[illegible] BTU/H/SQ FT
TOTALS	57 BTU/H/SQ FT

SOLAR ENERGY VS. SPACE HEATING NEEDS

$\frac{\text{57 BTU/H/SQ FT (24 HRS)}}{30°}$ = 27 BTU/SQ FT./ DEGREE DAY

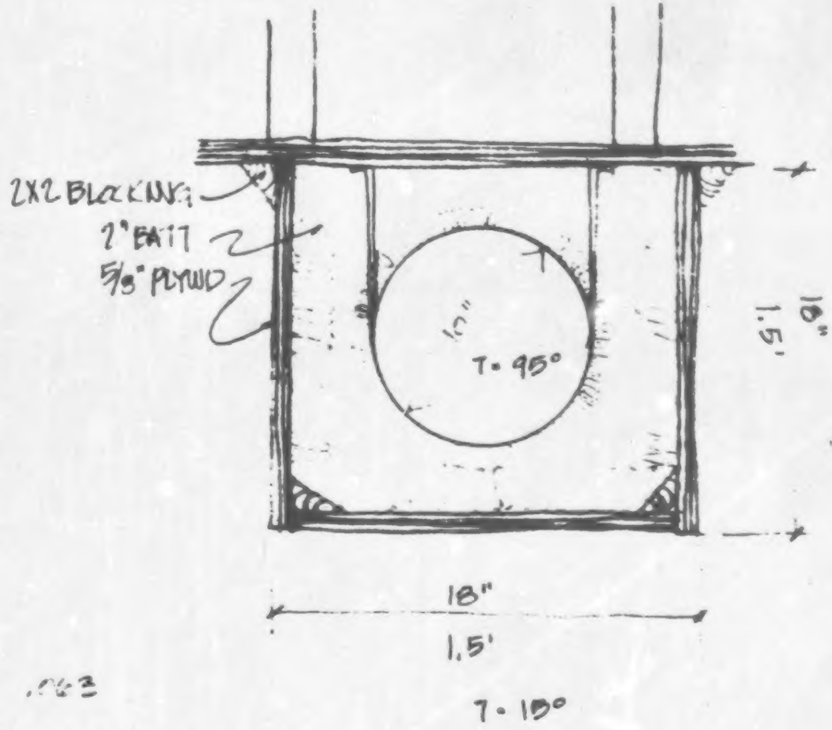
SOUTH FACING COLLECTOR 60° SLOPE 800 SQ FT 61 % FLOOR AREA
40% EFFICIENT 325 SQ FT 25 % FLOOR AREA

TYPICAL YEAR

	AVE. DEG DAYS		SPACE HEATING NEEDS/DAY		APPLIANCE HEAT	SOLAR ENERGY COLLECTED / DAY		
						PER/SQ FT	800 SQ FT	325 SQ FT
JAN	766	25	675	876 000	130000	265	185 500	86000
FEB	597	21	567	736 000	120 000	293	205 000	95 000
MAR	574	18.5	500	650000	115000	397	278000	129 000
APR	456	15	405	526000	105 000	427	300000	139 000
MAY	289	9	243	316 000	90000	488	341000	159 000
JUNE	123	4	108	140000	85000	480	336000	156000
JULY	37	1	27	35000	75000	555	389000	181000
AUG	34	1	27	35000	75000	572	400000	186000
SEP	119	4	108	140000	85000	596	418000	194000
OCT	366	12	325	422000	95000	447	312000	146000
NOV	580	19	513	666000	115000	247	172900	81000
DEC.	729	23.5	635	824230	130000	160	112000	52000
	PER MO	PER DAY						

1 CONSERVATION METHOD

ENCLOSING DUCT WORK UNDER FLOOR



SAVINGS

"R" AS IS 1.89 "U" = .20

NEW "R"

INSIDE AIR FILM	.17
METAL DUCT	0
1" INSULATION	4.55
AIR SPACE	1.01
2" BATT INS.	9.1
5/8" PLYWOOD	.78
OUTSIDE AIR FILM	.17

$\Sigma R = 15.78$ $\frac{1}{\Sigma R} = .063$

AREA = 3 X 1.5' (18") 80 = 360 SQ FT

$360 (.063)(80) = \frac{1814.4 \text{ BTU/H}}{1298} = 1.3$ BTU/H/SQ FT

AS COMPARED TO 2.7 BTU/H/SQ F

52% REDUCTION

ALSO 128 SQ FT OF FLOOR AREA LOSS
CAN BE SUBTRACTED = 706 - 128 = 578 (50)(.073) = 2109 BTU/H REDUCING SKIN LOSS TO
42.4 BTU/H SQ FT

COST:	360 SQ FT PLYWOOD @ $.40/SQ FT	=	$144
	2" BLOCKING		$60
	INSULATION @ $.18 SQ FT	=	$65
			$269

2 CONSERVATION METHOD

BY PLACING DOUBLE GLASS INTO EXISTING
WINDOW FRAMES

SAVINGS

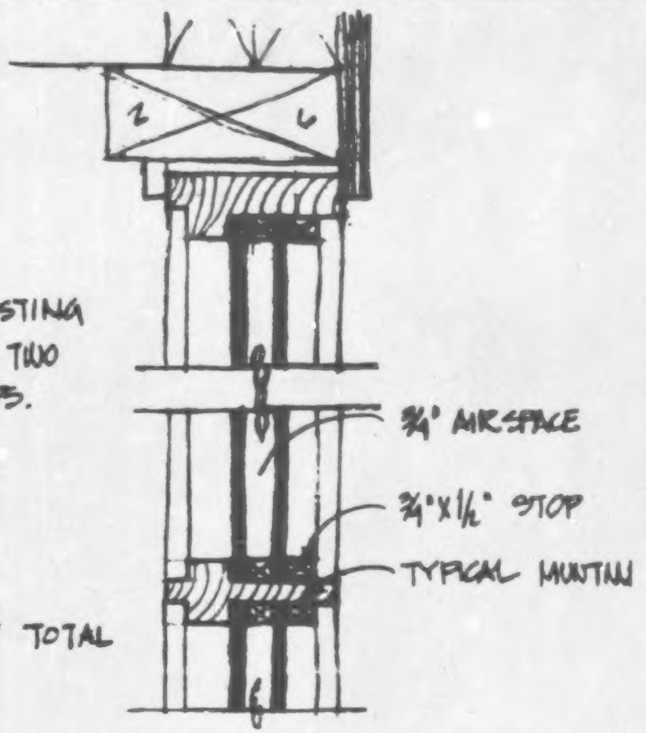
"U" AS IS 1.13

DOUBLE PANE GLASS "U" = .62

LOSS = 750 (.62)(50) = 23250 BTU/H

COMPARED TO 42375 BTU/H
A 44% REDUCTION IN GLASS LOSSES

THIS REDUCES 44 BTU/H/SQ FT TO 29.2 BTU/H/SQ FT TOTAL



SPLITTING EXISTING
1 1/2" STOP TO TWO
3/4"X1/2" STOPS.

NEW INSTALLATION EXAMPLE

COST:

GLASS ONLY	$3.70/SQ FT =	$2,775.00
RESAWING STOPS	$.40/SQ FT	300.00
WASHING EXISTING WINDOWS	$100 APPROX	100.00
	TOTAL	$3,175.00

ADDING THIS SAVINGS TO THE BOXING IN OF DUCT WORK 29.2 BTU/H/SQFT
− 1.4 BTU/H/SQFT

NEW SKIN & DUCT LOSS 27.8 BTU/H/SQFT
INFILTRATION + 9.7

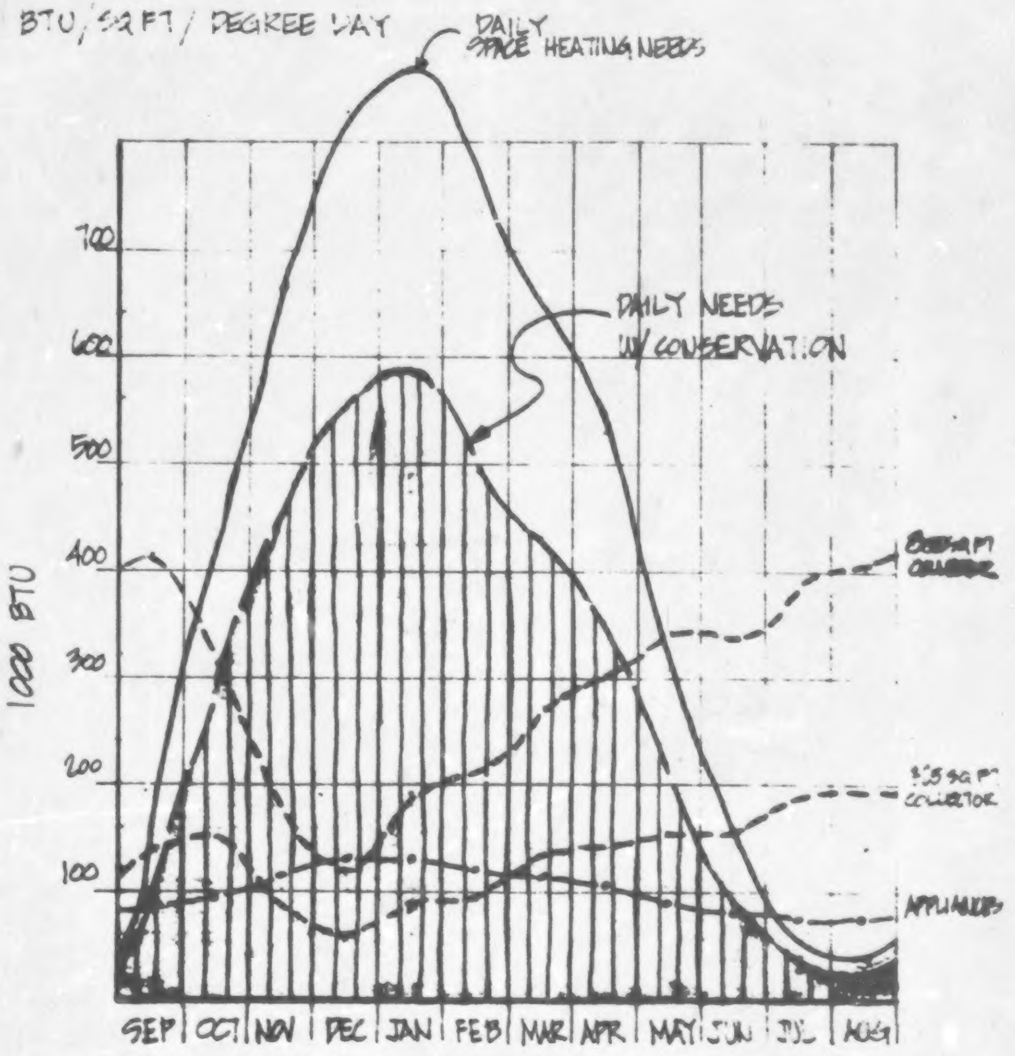
NEW TOTAL 37.5 BTU/H/SQ FT

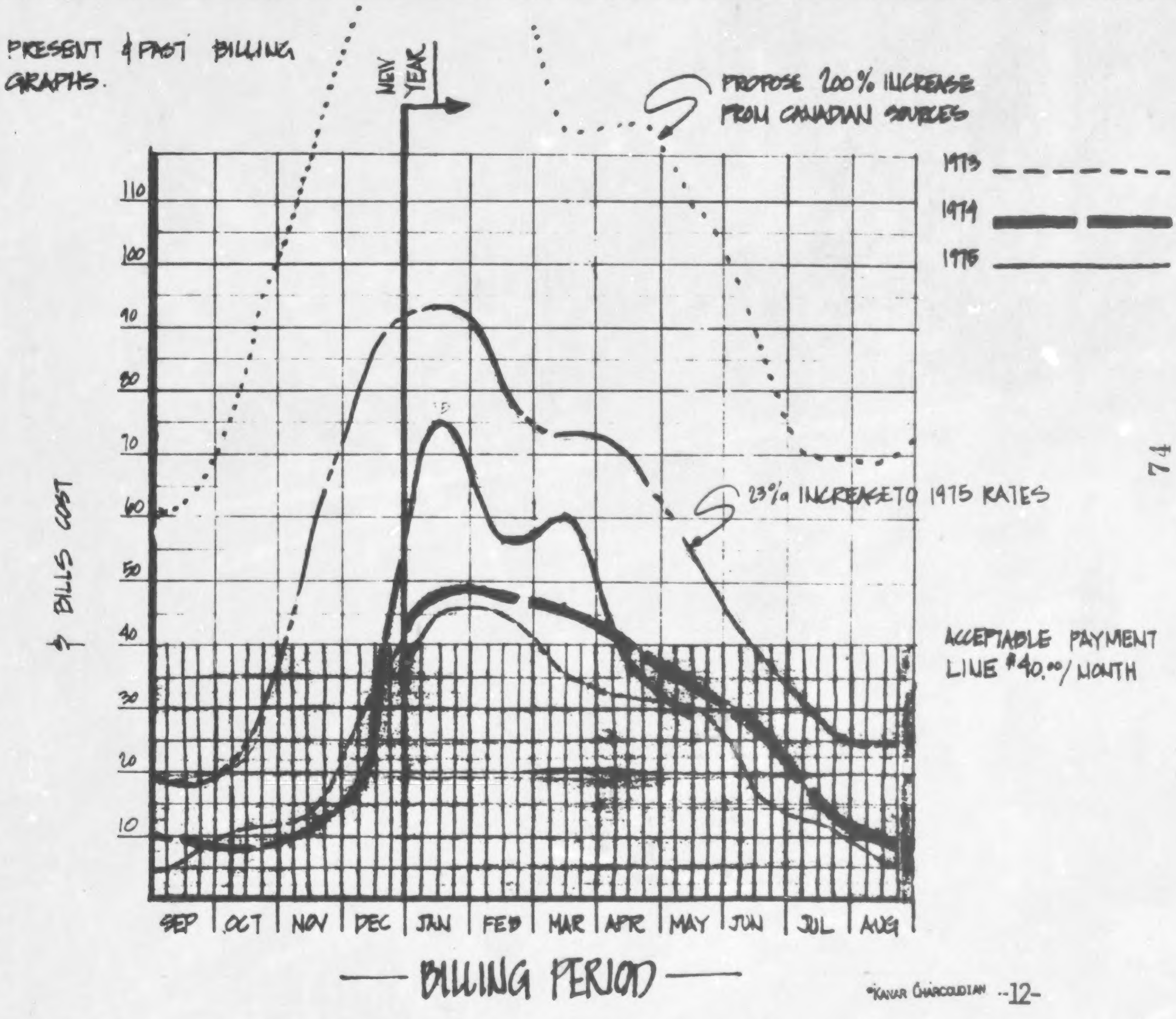
NEEDS VS. SUPPLY

USING NEW REDUCED BTU/H/SQ FT

$$\frac{37.5\ (24)}{50°} = 18\ \text{BTU/SQ FT/DEGREE DAY}$$

	DEG. DAYS PER MO	PER DAY	SPACE HEAT NEEDS/DAY	
JAN	766	25	450	584000
FEB	597	21	378	491000
MAR	574	18.5	333	432000
APR	456	15	270	351000
MAY	289	9	162	211000
JUN	123	4	72	93500
JUL	37	1	18	24000
AUG	34	1	18	24000
SEP	119	4	72	93500
OCT	366	12	216	251000
NOV	580	19	342	444000
DEC	729	23.5	423	550000





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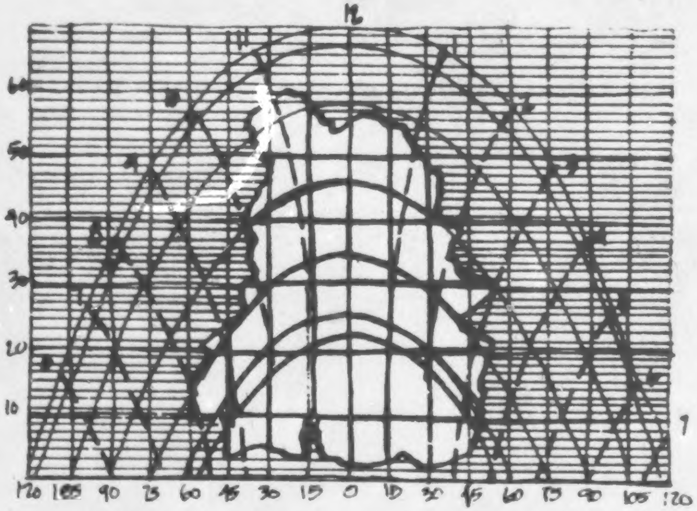
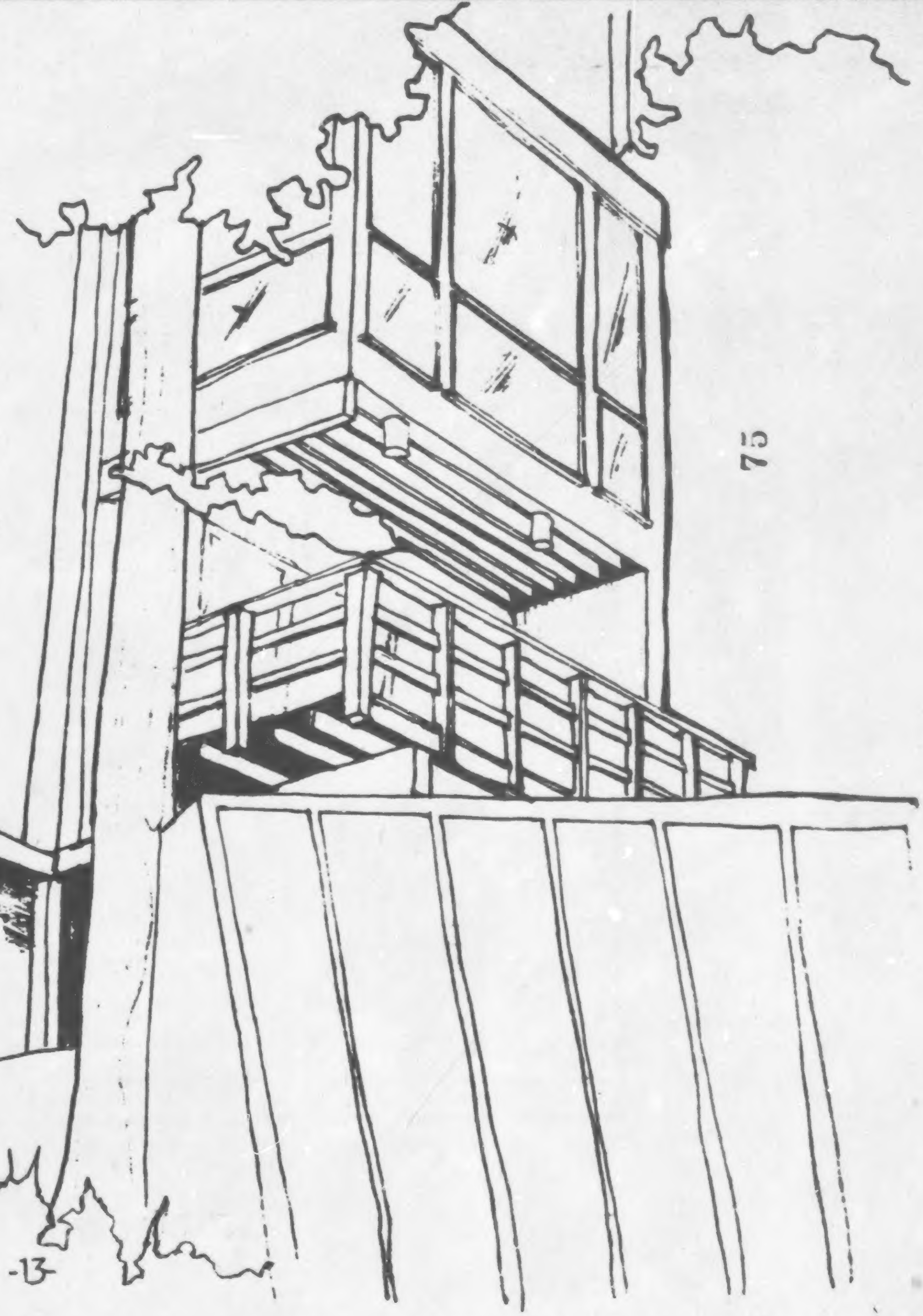


HORIZON CHART BELOW DECK (SOUTH) LOCATION

ALTERNATE LOCATION FOR HOT WATER COLLECTOR BELOW SOUTH DECK OFF SEWING-STUDY ROOM. GOOD LOCATION FOR WINTER MONTHS BUT OVERHANGING TREES LIMIT SUMMER EFFECTIVENESS.



PHASE 2

HOT WATER COLLECTOR

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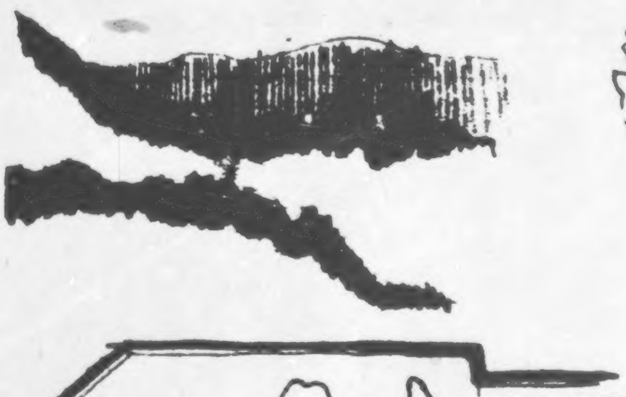
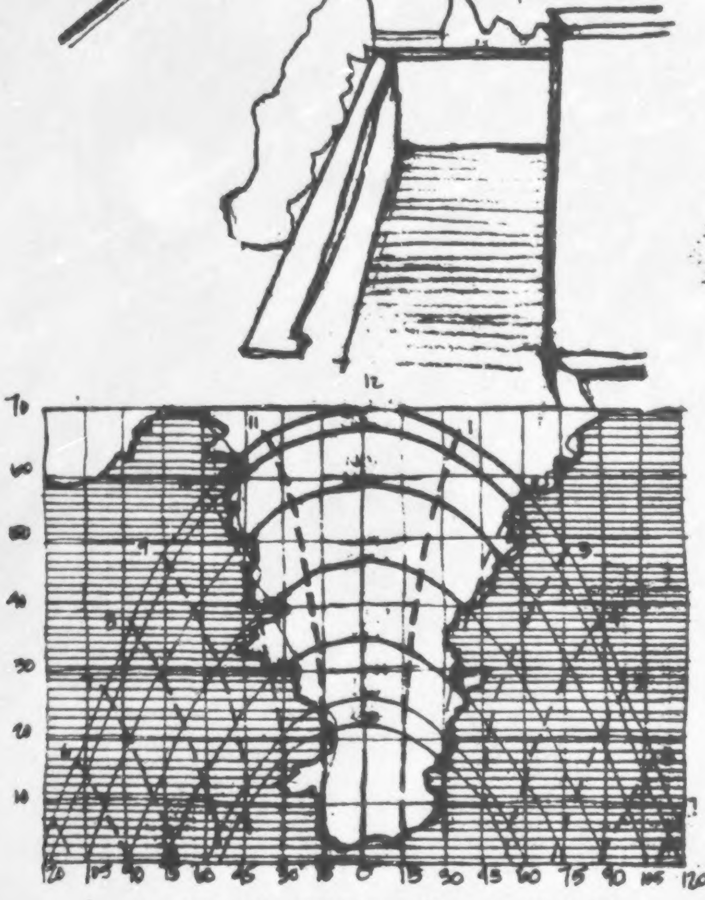
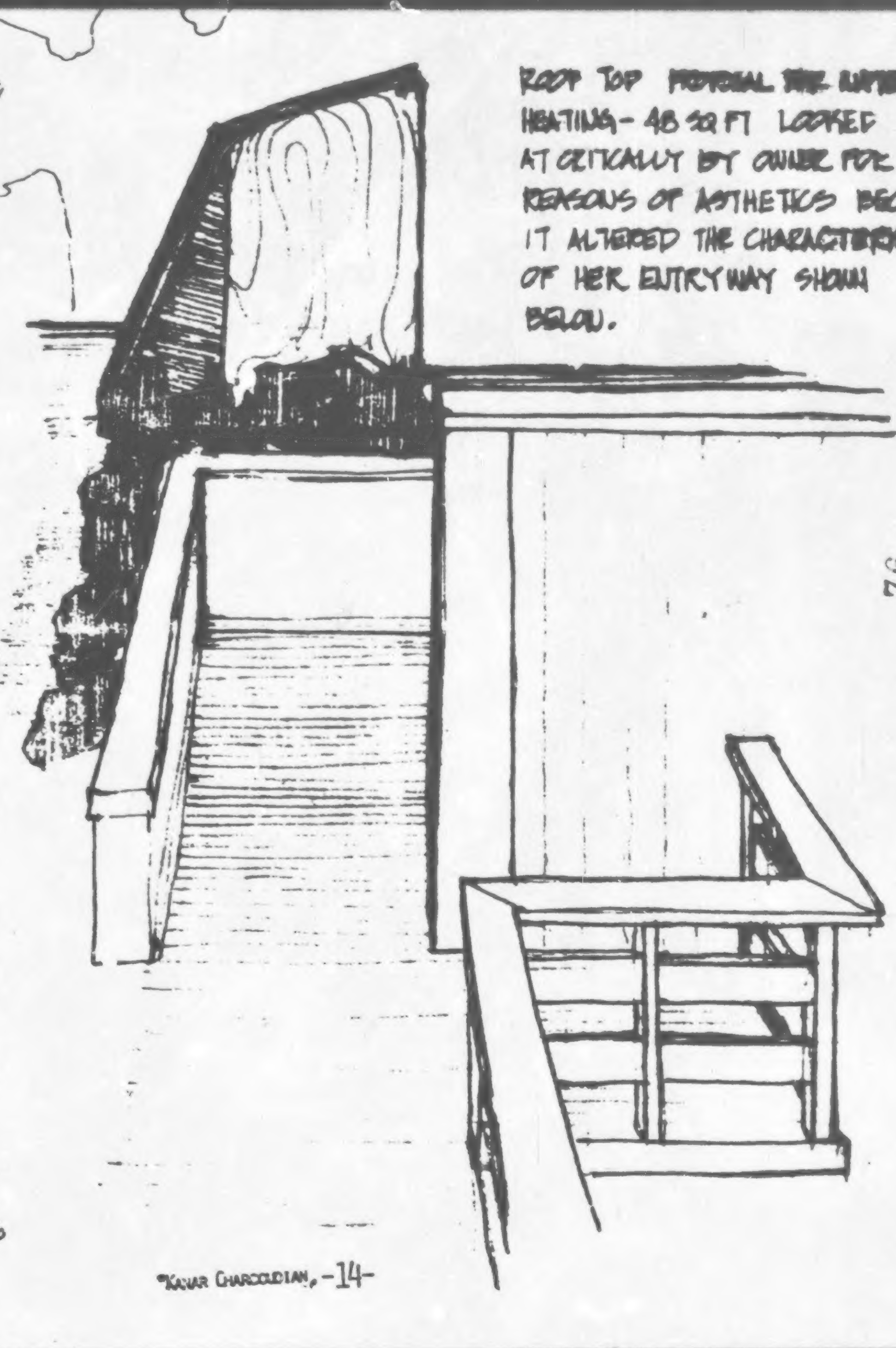
ROOF TOP PROPOSAL FOR WATER HEATING - 48 SQ FT LOOKED AT CRITICALLY BY OWNER FOR REASONS OF ASTHETICS BECAUSE IT ALTERED THE CHARACTERISTICS OF HER ENTRYWAY SHOWN BELOW.



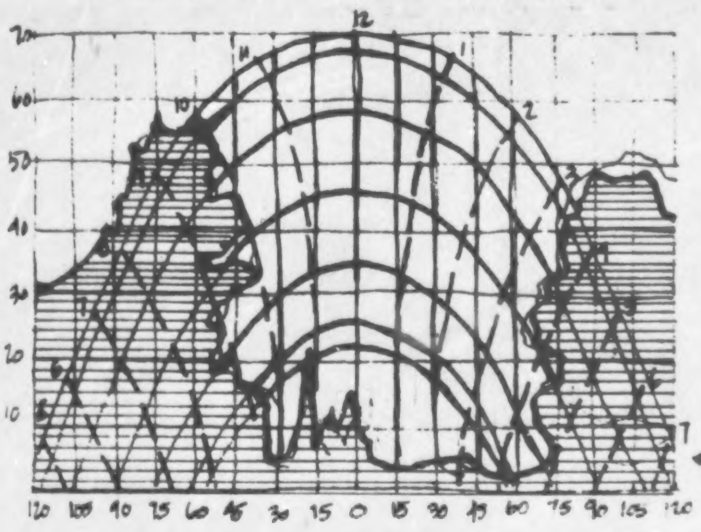


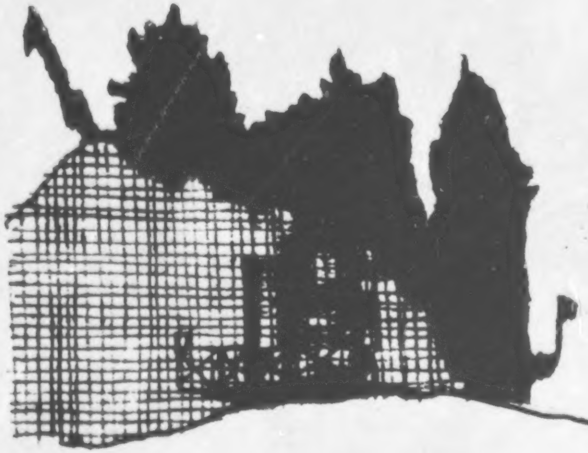
HORIZON CHART ROOF LOCATION



©KAVAR CHARCOUDIAN, -14-

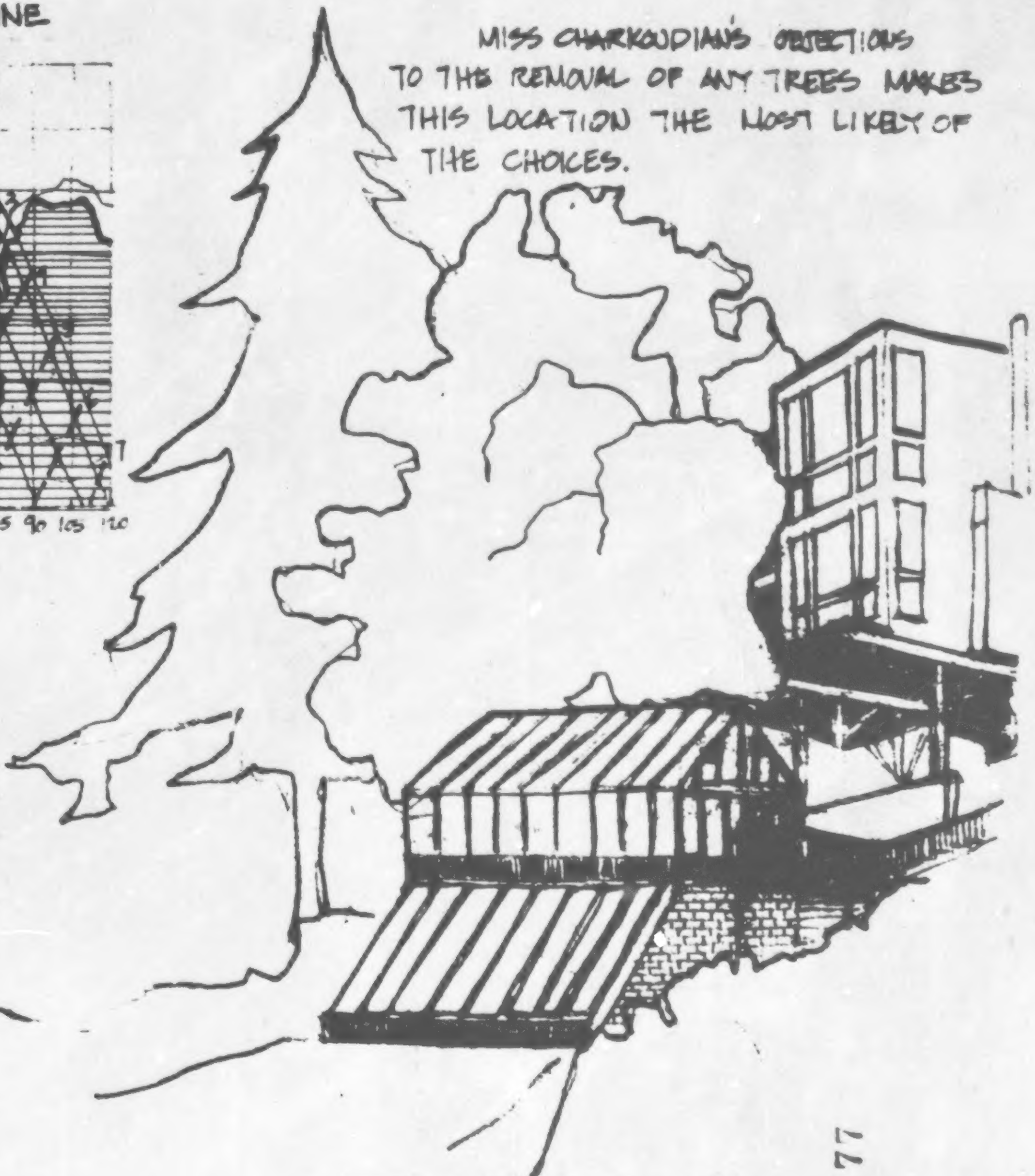
HORIZON CHART BELOW TREE LINE





TREES IN BACK
TREES IN FRONT

MISS CHARKOUDIAN'S OBJECTIONS
TO THE REMOVAL OF ANY TREES MAKES
THIS LOCATION THE MOST LIKELY OF
THE CHOICES.

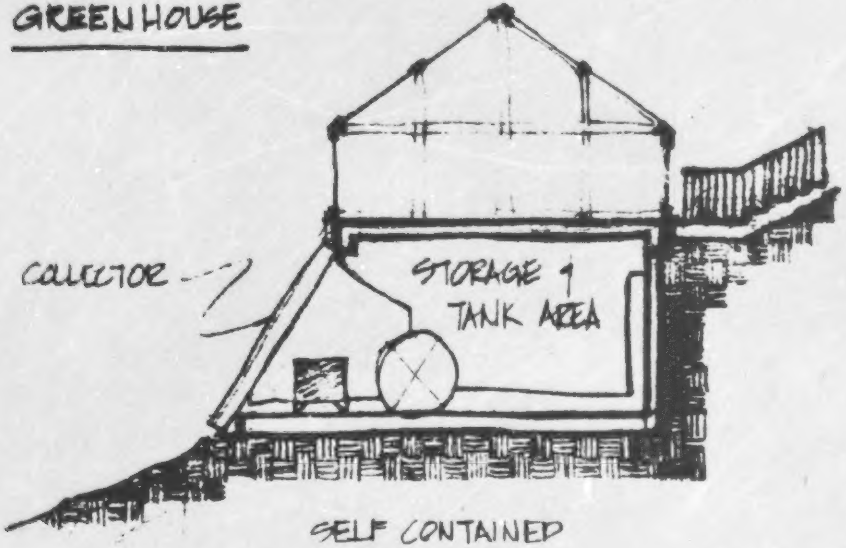


PHASE 3

HOUSEHOLD HEATING SUPPLEMENTATION

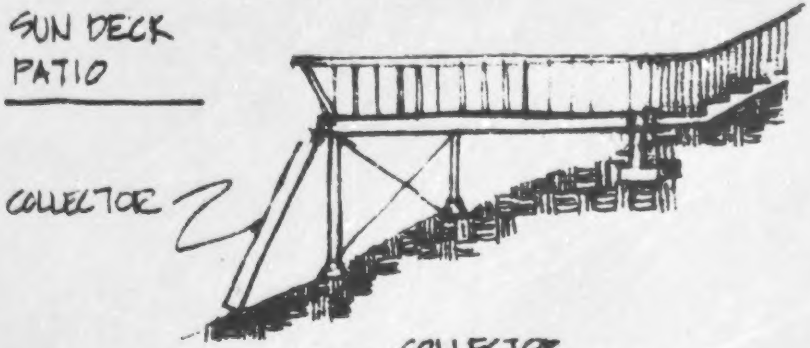
*KAVAR CHARCOUDIAN

GREENHOUSE



SELF CONTAINED

SUN DECK PATIO



COLLECTOR STORAGE UNDER HOUSE

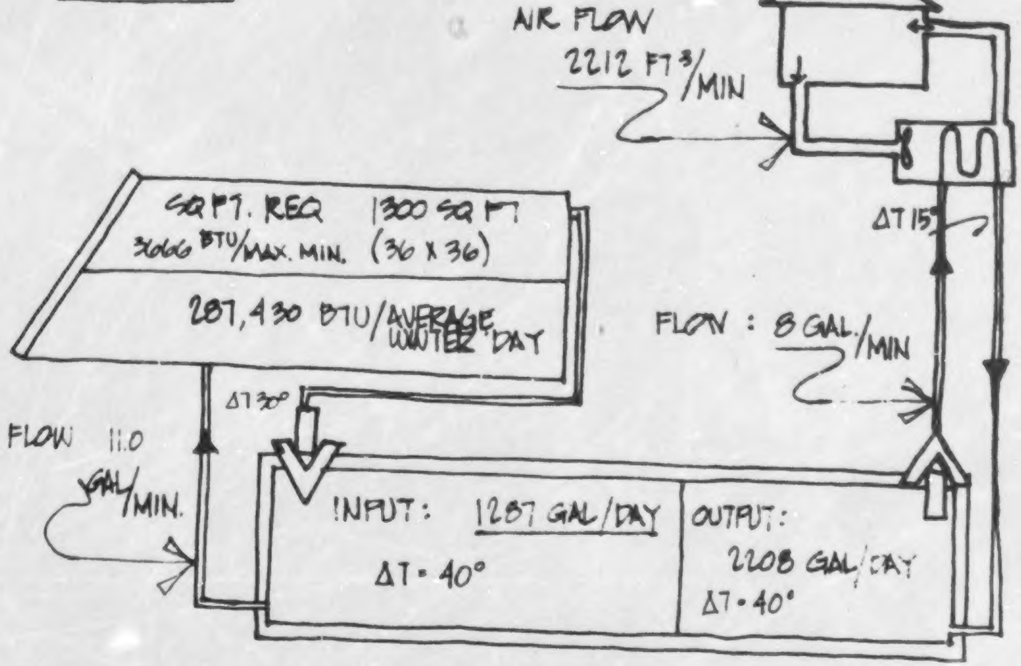
THIS LOCATION PROBABLY THE OPTIMUM POSITION IN REGARD TO THE SITE & HOUSE LOCATION. THE ADDITION OF THE GREEN HOUSE OR DECK WOULD PROVIDE ALSO SOME USE OF THE SITE BY THE OWNER. WOULD ALSO PROVIDE THE OPPORTUNITY FOR THE OWNER TO BE INVOLVED WITH THE COLLECTOR & SEE ANY MALFUNCTION & TO CLEAN FOR MAXIMUM EFFICIENCY.

PROBLEMS WITH THESE SOLUTIONS ARE COST:

BY BUILDING A SELF CONTAINED UNIT COST IS INCREASED BUT ALL EQUIPMENT IS IN ONE LOCATION. HOWEVER COST IS AT THE LEAST PROHIBITIVE IF NOT DISILLUSIONING
DECK IDEA IS PROBABLY CHEAPER TO CONSTRUCT HOWEVER COSTS OF RUNNING PIPES TO HOUSE LOCATION IS DETERMINING FACTOR.

SEE PHASING & COST ESTIMATIONS.

SIZING


AIR FLOW
2212 FT³/MIN
SQ FT. REQ 1300 SQ FT
3666 BTU/MAX. MIN. (36 X 36)
287,430 BTU/AVERAGE WINTER DAY
ΔT 15°
FLOW : 8 GAL./MIN
ΔT 30°
FLOW 11.0 GAL/MIN.
INPUT: 1287 GAL/DAY
ΔT = 40°
OUTPUT:
2208 GAL/DAY
ΔT = 40°

HOUSE AS IS:

60000 BTU/H HOUSE LOSS
27 BTU/SQ FT / DEGREE DAY

ΔT = 50°

736,000 BTU/DAY

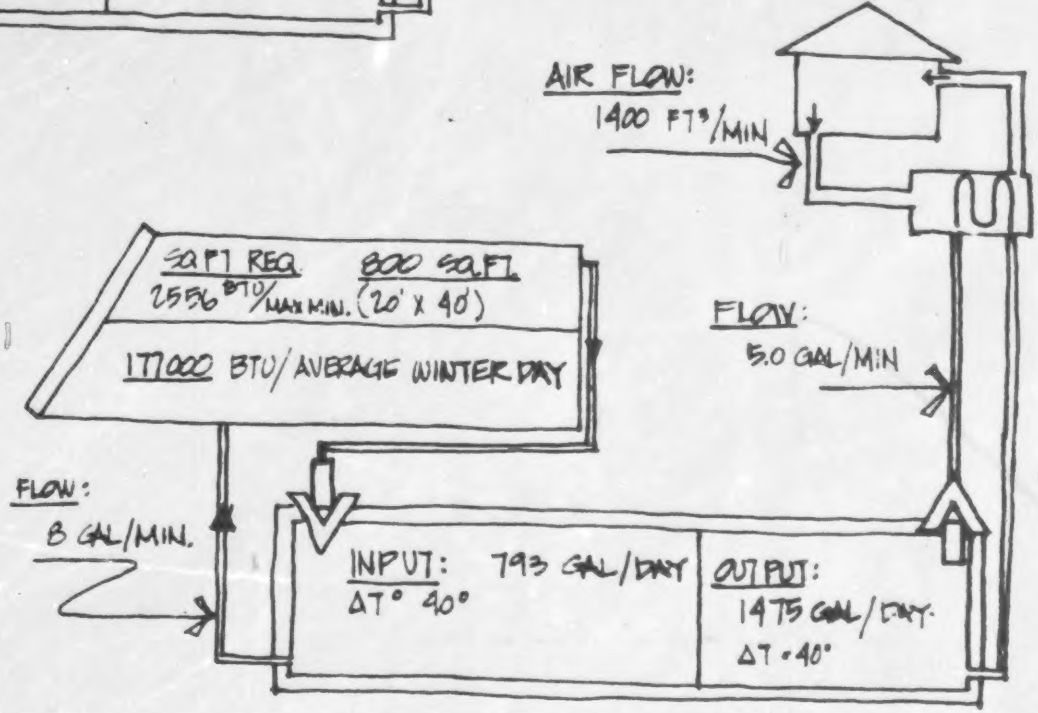
SUPPLEMENTING 40% HEATING
REQUIREMENTS :
1300 SQ FT COLLECTOR
2500 GAL STORAGE TANK

HOUSE : AFTER PHASE 1

38000 BTU/H
18 BTU/H/SQ FT
ΔT - 50°

491000 BTU/DAY

SUPPLEMENTING 40° HEATING
REQUIREMENTS:
800 SQ FT COLLECTOR
1500 GAL. STORAGE TANK


AIR FLOW:
1400 FT³/MIN
SQ FT REQ. 800 SQ.FT.
2556 BTU/MAX MIN. (20' X 40')
177000 BTU/AVERAGE WINTER DAY
FLOW:
5.0 GAL/MIN
FLOW:
8 GAL/MIN.
INPUT: 793 GAL/DAY
ΔT° 40°
OUTPUT:
1475 GAL/DAY.
ΔT = 40°

PHASING & COST

PHASE 1

THE IMPLEMENTATION OF THE REMODEL SUGGESTIONS MADE IN THE HEAT LOSS SECTION. THE ENCLOSURE OF THE PRESENTLY EXPOSED DUCT SYSTEM & THE ADDITION OF A SECOND LAYER OF GLASS TO THE EXPANSIVE AREAS OF WINDOWS. THESE TWO ADJUSTMENTS LOWER THE DAILY HEATING NEEDS (MAXIMUM) BY ALMOST 33%.

A COST BREAKDOWN IS LISTED IN HEAT-LOSS SECTION.

THE DUCT WORK - $270-300
THE WINDOWS $3000-3500

DOUBLE GLAZING CAN BE DONE IN SECTIONS ADDING WINDOWS ONE AT A TIME. PROBLEMS EXIST IN PREVENTING MOISTURE FROM ENTERING THE INSULATING AIR SPACE: VENT HOLES MIGHT BE SUCCESSFUL BUT ONLY TIME & EXPERIENCE WILL TELL.

PHASE 2

INSTALLING A SOLAR COLLECTOR FOR THE SUPPLY OF HOT WATER IN EITHER OF THE LOCATIONS MIGHT REDUCE THE NATURAL GAS HEATING BILLS 10-15%/MONTH. MAX BILL 1975 - 75.00 -10-15% - 67.50 - 63.75. THE AREA OF THIS COLLECTOR WOULD BE 48 SQ FT (6'X8'). THE ALTERNATIVE LOCATIONS FOR THIS COLLECTOR HAVE BEEN SHOWN.

COSTS:		
COLLECTOR	$5-7 / SQ FT	$ 240- 340
PUMP (APPROX)		$ 200
PIPING	100' @ $.80/FT (COPPER)	$ 80
THERMOSTAT		$ 100
MISC. FRAMING		$ 50
		$ 670-$770

*KANAR CHARCOUDIAN

PHASE 2 (CONT.)

PAY OFF TIME BASED UPON $75.00 MAX MO. BILL 9.50/MO SAVINGS

$$\frac{\$710.}{9.50} = 81 \text{ MO.} \quad 7 \text{ YEARS}$$

BUT WITH THE PROJECTED NATURAL GAS INCREASES IN THE, NOT TOO DISTANT FUTURE THE PAYOFF TIME MIGHT SHORTEN CONSIDERABLY. ALSO THE RESALE VALUE OF THE HOUSE, WITH THE TENDENCIES AT THE PRESENT, WILL GO UP AS THE COST OF AVAILABLE ENERGY INCREASES.

PHASE 3

THE THIRD, AND PROBABLY THE FINAL, SPACE HEATING SOLAR CONTRIBUTION, TO THE CHARKOUDIAN RESIDENCE. THE SHAPE & FORM OF THIS COLLECTION SYSTEM IS TOTALLY VARIABLE. BUT THE LOCATION, ACCORDING TO SITE RESTRICTIONS, IS ALMOST THE ULTIMATE IN RELATIONSHIP TO SUN ANGLE & ORIENTATION (SEE HORIZON CHART PHASE 3) BASED UPON SIZING CHART 800 SQ FT COLLECTOR WILL PROVIDE 25% OF "HOUSE AS IS NEEDS". REDUCING MAX 1975 PAYMENT BY 25% = $75.00 − 25% = $56.00 SAVINGS OF $18.00 BY PROVIDING A DECK OR GREENHOUSE IN THE AREA OF THE COLLECTOR IT GIVES MISS CHARKOUDIAN AN OPPORTUNITY TO USE THIS AREA OF HER SITE WHICH AT THE PRESENT IS NOT USED. IT ALSO GIVES HER A CHANCE TO OBSERVE THE PROPER FUNCTION OF THE COLLECTOR & PREVENT INEFFICIENCY.

COSTS: BASED UPON APPROX. TOTAL BLDG COST.

DECK PROPOSAL: AREA 500 SQ FT. @ $13/SQ FT (MATERIALS & LABOR) − $6500

PHASE 3 (CONT.)

500 SQ FT. DECK	$ 6500
800 SQ FT COLLECTOR @ $5-7/SQ FT	$ 4000 - 5600
1500 GAL STOR. TANK	$ 1200
PUMP	$ 200
COPPER PIPE 200 FT @ $.80/FT	$ 160
CONNECT TO STORM DRAIN	$ 60
THERMOSTAT	$ 100
TOTALS	$ 9,520.00
WITHOUT DECK	$ 3700.00

SELF CONTAINED
GREEN HOUSE PROPOSAL:

BUILDING APPROX 350 SQ FT (20'x 18')
BUILDING COSTS (CONC) $23.00/SQ FT

350 SQ FT BLDG.	$ 8050
800 SQ FT COLLECT.	$ 4000 - 5600
1500 GAL STOR. TANK	$ 1200
PUMP	$ 200
COPPER PIPE 200 FT	$ 160
STM DRAIN CONNECT	$ 60
THERMOSTAT	$ 100
GREENHOUSE PREFAB - SEARS 200□'	$ 1400
TOTALS	$ 15,170 !!!

REVIEW SUGGESTIONS

THE BASIC CONCERN WITH THE REVIEWERS WAS THAT THE COST ESTIMATES WERE BASED STRICTLY ON PURE MONEY (NO INTEREST, INFLATION RATES). THESE, OF COURSE, WOULD CHANGE FIGURES DRASTICALLY. HOWEVER, WITHOUT UNDERSTANDING COMPLETELY WHAT THESE VARIABLES INVOLVED, WE FELT THAT WE COULD NOT INCORPORATE THEM ACCURATELY

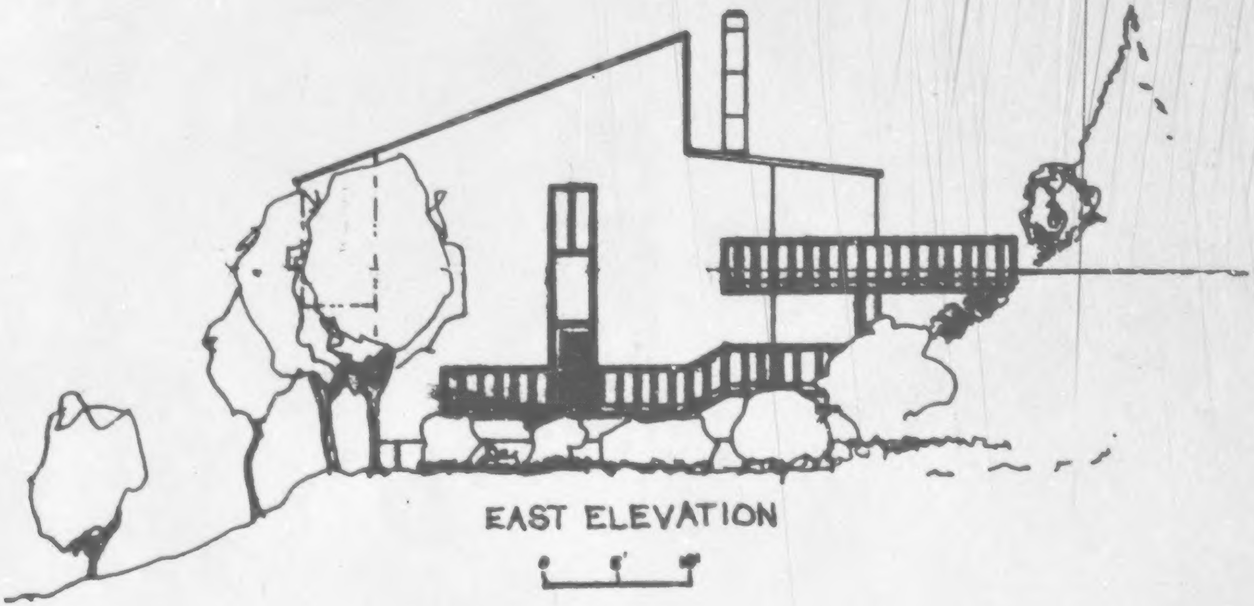
A COMMENT, FROM THE ARCHITECT HIMSELF, WAS THAT IT WOULD BE RIDICULOUS TO PROVIDE THE HOUSE WITH SOLAR COLLECTORS AS IT STANDS NOW. THERE MUST BE SOME REALISTIC MODIFICATIONS TO THE ENERGY SAVING QUALITIES (OR LACK OF) OF THE HOUSE. SOME OF HIS SUGGESTIONS WERE; ① INSTEAD OF FRAMING IN THE DUCTS AS SHOWN EARLIER, FRAMING IN THE ENTIRE LOWER EXPOSE AREA WITH A PERIMETER FRAMED WALL, SIDED WITH IDENTICAL SIDING AS HOUSE. HIS FEELINGS WERE THAT THIS WOULD BE LESS EXPENSIVE, LABOR WISE, THAN ALL THAT WOULD BE INVOLVED IN THE DUCT WORK FRAMING. ② HAVING THE OWNER INSTALL INTERIOR WINDOW PANELS THAT COULD BE SLID INTO POSITION ALONG A RUNNER ATTACHED HORIZONTALLY TO THE EXISTING MUNTINS. THESE PANELS COULD BE INSTALLED DURING THE DAYTIME HOURS WHEN THE HOUSE IS NOT OCCUPIED, THEN OPENED DURING EVENING HOURS, THEN CLOSED AGAIN AT BEDTIME, THUS REDUCING GLASS LOSSES DURING PEAK HOURS: A MAJOR PERCENTAGE OF HEAT LOSS.

THESE SUGGESTIONS AS WERE ALL OTHERS WERE BASED UPON COST. AS A DIRECT RELATIONSHIP TO SAVINGS (PAYOFF) HOWEVER, ANOTHER OF OUR CONCERNS WAS IN QUESTION FORM: DOES IT MAKE SENSE TO SPEND $5-7/SQFT OF COLLECTOR THAT IS ONLY 33% EFFICIENT? WILL IT BE POSSIBLE TO WAIT UNTIL COLLECTORS ARE $5-7/SQFT BUT 85-90% EFFICIENT?

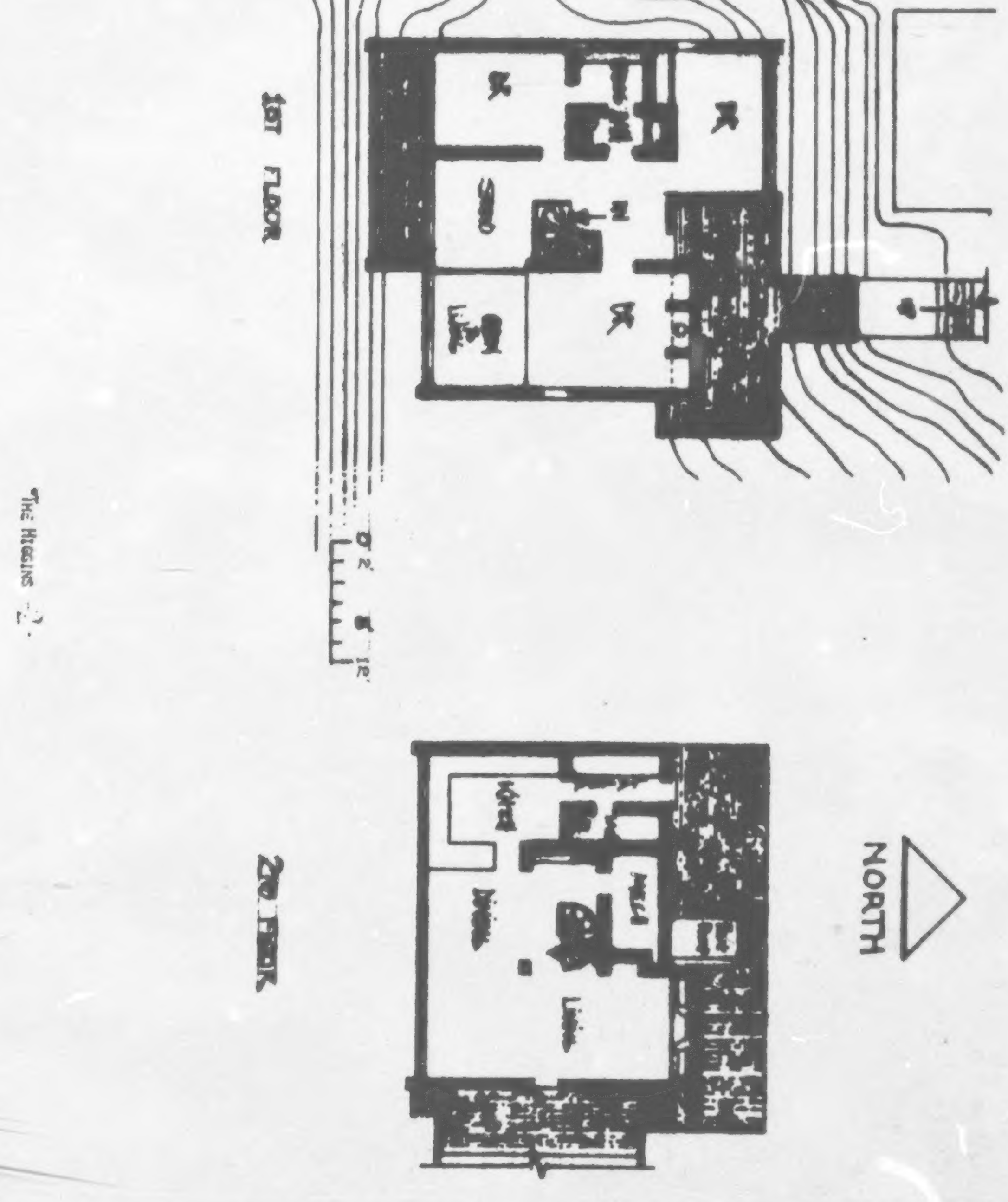
OWNER REACTIONS

THE SUGGESTIONS PUT FORTH IN OUR REPORT PLUS THE ONES BROUGHT OUT AT THE REVIEW, HAVE PLEASED THE OWNER. SHE FEELS IT IS HER PROBLEM NOW, TRYING TO DECIDE WHICH TO DO FIRST. HER PROBLEM IS FINANCIAL LEANING TOWARDS AESTHETICS. SHE WANTS HER HOUSE TO REMAIN THE SAME IN APPEARANCE, YET FUCTION MORE RESOURCEFULLY. FOR THIS SHE IS WILLING TO PAY, BUT ONLY FOR RESPONSIBLE SOLUTIONS. WE HAVE BROUGHT TO LIGHT SIGNIFICANT INFORMATION, MUCH OF WHICH SHE (AS WELL AS WE), WAS NOT AWARE. BUT THIS IS ONLY A BEGINNING FROM WHICH SHE CAN WORK. SHE REPORTS TO US THAT SHE IS GRATEFUL.

HIGGINS RESIDENCE



EAST ELEVATION


THE HIGGINS
1ST FLOOR
2ND FLOOR
NORTH
0 2 6 12

HEAT LOSS

AREAS

1ST FLOOR = 830
2ND FLOOR = 995
TOTAL = 1825 SQ. FT.

VOLUME

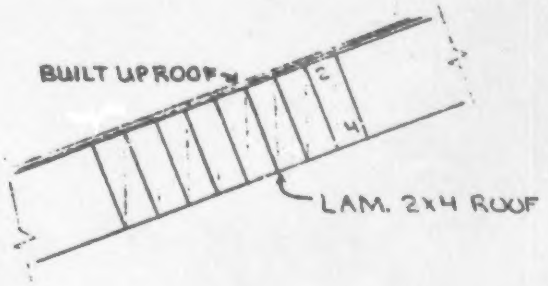
TOTAL VOLUME = 17220 CU. FT.

.DESIGN TEMPERATURE

65° F INSIDE - 15° OUTSIDE = 50° ΔT

RULE OF THUMB HEAT LOSS

1825 SQFT × 40 BTUH = 73000 BTUH



TOTAL ROOF AREA = 821 SQFT

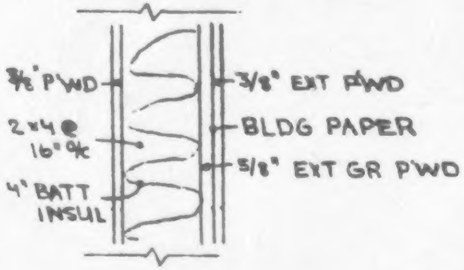
LOSS = 821 × 0.18 × 50 = 7389 BTUH

ROOF

OUTSIDE AIR FILM	R = 0.17
3/8" BUILT UP ROOF	R = 0.33
3 1/2" WOOD	R = 4.55
INSIDE AIR FILM	R = 0.62
	$R_T = 5.67$

$$U = \frac{1}{R_T} = 0.18$$

EXTERIOR WALLS


3/8" P'WD
2×4 @ 16" O/C
4" BATT INSUL
3/8" EXT P'WD
BLDG PAPER
5/8" EXT GR P'WD

OUTSIDE AIR FILM	R= 0.17
3/8" EXT GR. P'WD	R= 0.59
BUILDING PAPER	R= 0.06
5/8" EXT GR P'WD	R= 0.78
4" BATT INSULATION	R= 12.48
3/8" PLYWOOD	R= 0.59
INSIDE AIR FILM	R= 0.62

$R_T = 15.29$

$1/R = U = 0.065$

FIREPLACE WALL R= 15.17

$1/R = U = 0.066$

KITCHEN WALL W/CABINETS R= 19.61

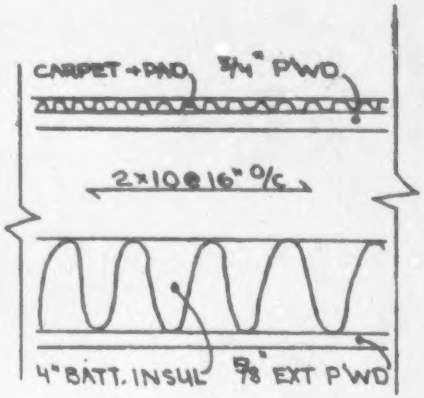
$1/R = U = 0.051$

KITCHEN WALL W/COUNTER R= 20.00

$1/R = U = 0.050$

LOSS THROUGH WALLS = 6662 BTUH

FLOOR


CARPET + PAD
3/4" P'WD
2×10 @ 16" O/C
4" BATT. INSUL
5/8" EXT P'WD

INSIDE AIR FILM	R= 0.17
CARPET W/PAD	R= 2.08
3/4" PLYWOOD	R= 0.94
5 1/4" AIR SPACE	R= 1.22
4" BATT INSULATION	R= 12.48
5/8" EXT GR P'WD	R= 0.18
OUTSIDE AIR FILM	R= 0.62

$R_T = 12.81$

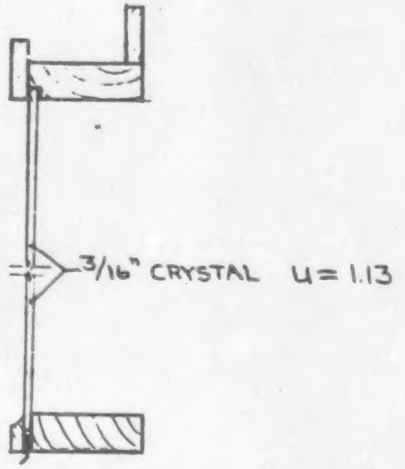
$U = 0.053$

KITCHEN FL W/ TILE R= 17.66

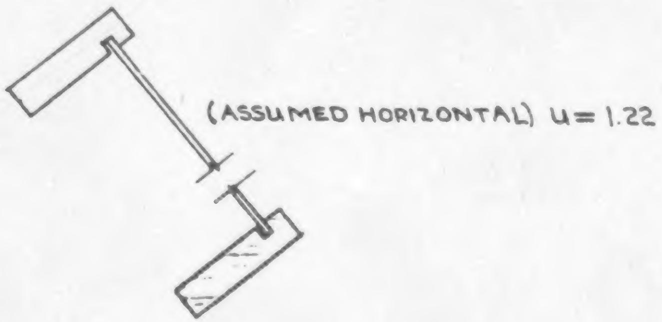
$U = 0.057$

LOSS THROUGH FLOOR = 1993 BTUH

VERTICAL GLASS


3/16" CRYSTAL
U= 1.13

SKYLIGHT


(ASSUMED HORIZONTAL) U= 1.22

LOSS THROUGH GLASS = 40350 BTUH

LUNG LOSS

ONE AIR CHANGE PER HOUR
LOSS= 17220 × 0.18 × 50
= 15499 BTUH

TOTAL LOSS

SKIN LOSS

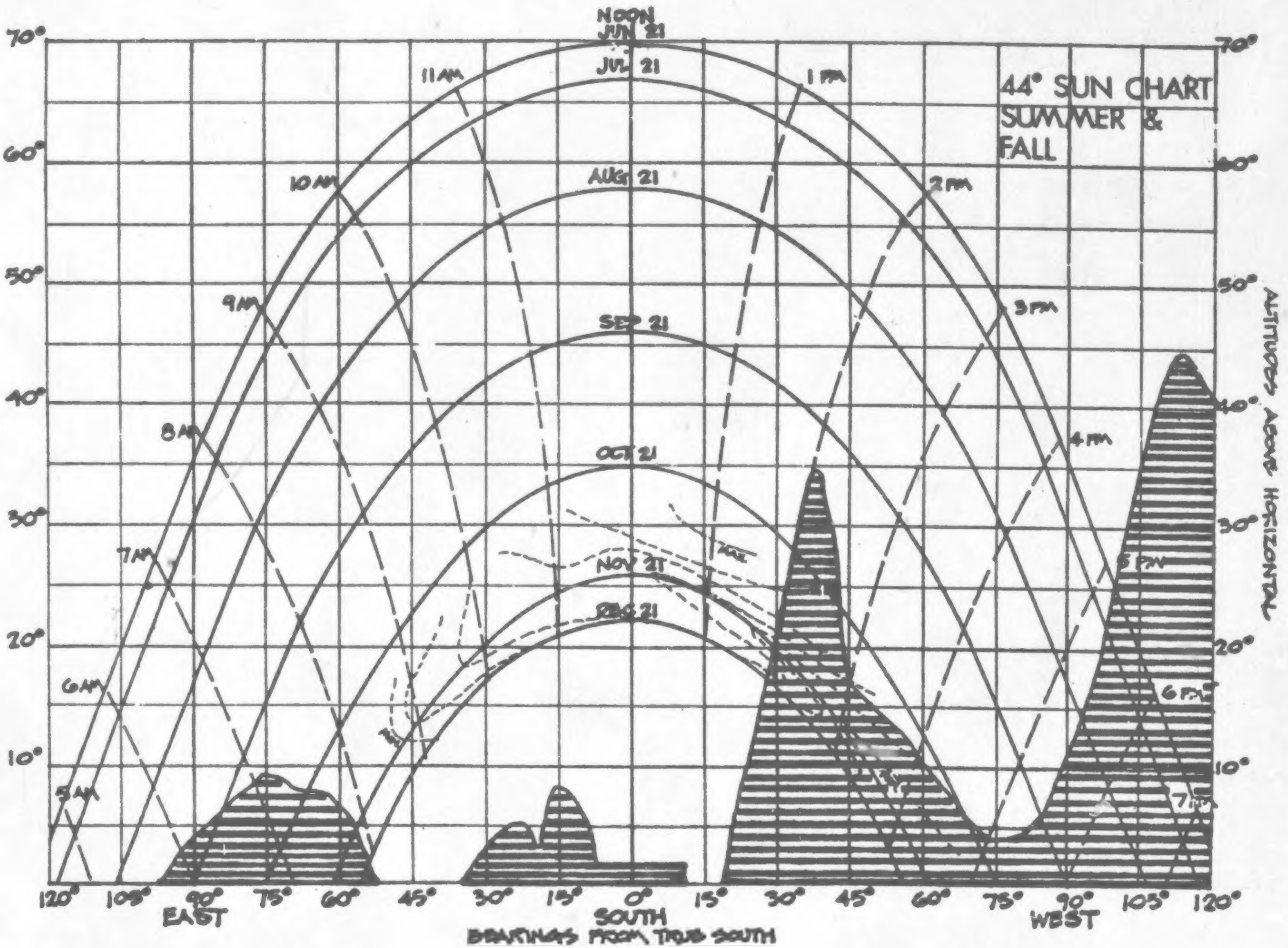
ROOF = 7389
WALLS = 6662
FLOOR = 1993
GLASS = 40350
56394 BTUH

LUNG LOSS = 15499 BTUH

TOTAL HEAT LOSS = 71,893 BTUH

PER SQ. FT. FLOOR AREA = 39.4 BTUH

PER DAY = 1,725,432 BTUD
(IF ENTIRE DAY @ 15°F...)



DRIVEWAY

The Higgins -6-

NEED AND SUPPLY

ILLUSTRATION OF PORTION OF SPACE HEATING NEEDS THAT COULD BE MET, ON AN AVERAGE DAILY BASIS, BY SOLAR ENERGY.

HIGGINS HOUSE = 1825 SQ FT. HEATED FLOOR AREA

HEAT LOSS AT ΔT = 39 ^{BTU}/SQFT. AS IS, 28.4 ^{BTU}/SQ FT CONS.

BTUH LOSS/DEGREE DAY = $\frac{\text{BTU/SQ FT} \times \text{24 HR.}}{\Delta T}$ = 18.7 AS IS, 13.6 CONS.

AVE. DEGREE DAYS EUGENE, OREGON						DAILY HEAT FROM APPLIANCES
MO	PER MO.	PER DAY	BTUD / SQFT	TOTAL AS IS	TOTAL CONSV.	BTU
JAN	766	25	468 340	854100	620500	134000
FEB	597	21	393 286	717225	521950	120000
MAR	574	18.5	346 252	631450	459900	115000
APR	456	15	281 204	512825	372300	105000
MAY	289	9	169 122	308425	222650	99000
JUNE	123	4	75 54	136875	98550	85000
JULY	37.	1	18.7 13.6	34128	24820	75000
AUG	34	1	18.7 13.6	34128	30295	75000
SEPT	119	4	75 54	136875	98550	85000
OCT	366	12	225 163	410625	297475	95000
NOV	580	19	356 258	649700	470850	115000
DEC	729	23.5	440 320	803000	534000	130000

CONSERVATION

REDUCTION IN BTUH HEAT LOSS WHICH COULD BE EXPECTED AS THE RESULT OF CONSERVATION MODIFICATIONS TO THE HIGGINS HOUSE.

I ADDITION OF 2" EXPANDED POLYURETHANE FOAM INSULATION TO ROOF DECK.

ROOF U WITHOUT INSULATION = 0.18
ROOF U WITH INSULATION = 0.057

LOSS THROUGH ROOF AS IS = 7389 BTUH

LOSS WITH INSULATION = AREA × U × ΔT = 2340 BTUH

REDUCTION IN LOSS = 7389 - 2340 = 5049 BTUH

% OF TOTAL = $\frac{5049}{71893}$ = 0.07 = 7% REDUCTION

II INSTALLATION OF INSULATING GLASS
COST: APPROX $7.00 / SQFT = 7.00 × 700 = $4900

GLASS (DOUBLE W 1/4" AIR SPACE) U = .73

LOSS THROUGH GLASS AS IS = 28966 BTUH

LOSS WITH INSULATING GLASS = AREA × U × ΔT = 18725 BTUH

SKYLIGHT (DOUBLE W 1/4" AIR SPACE U = .70

LOSS THROUGH SKYLIGHT AS IS = 11385 BTUH

LOSS WITH INSULATION = AREA × U × ΔT = 6545 BTUH

REDUCTION IN LOSS = 40351 - 25270 = 15081 BTUH

% OF TOTAL = $\frac{15081}{71893}$ = 0.21 = 21% REDUCTION

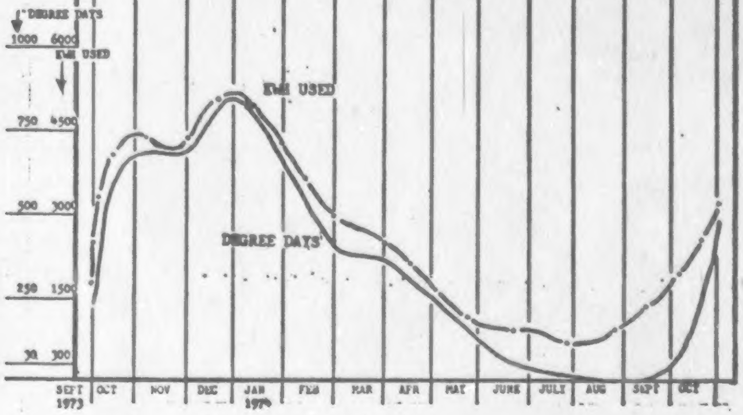
TOTAL REDUCTION POSSIBLE = 28%

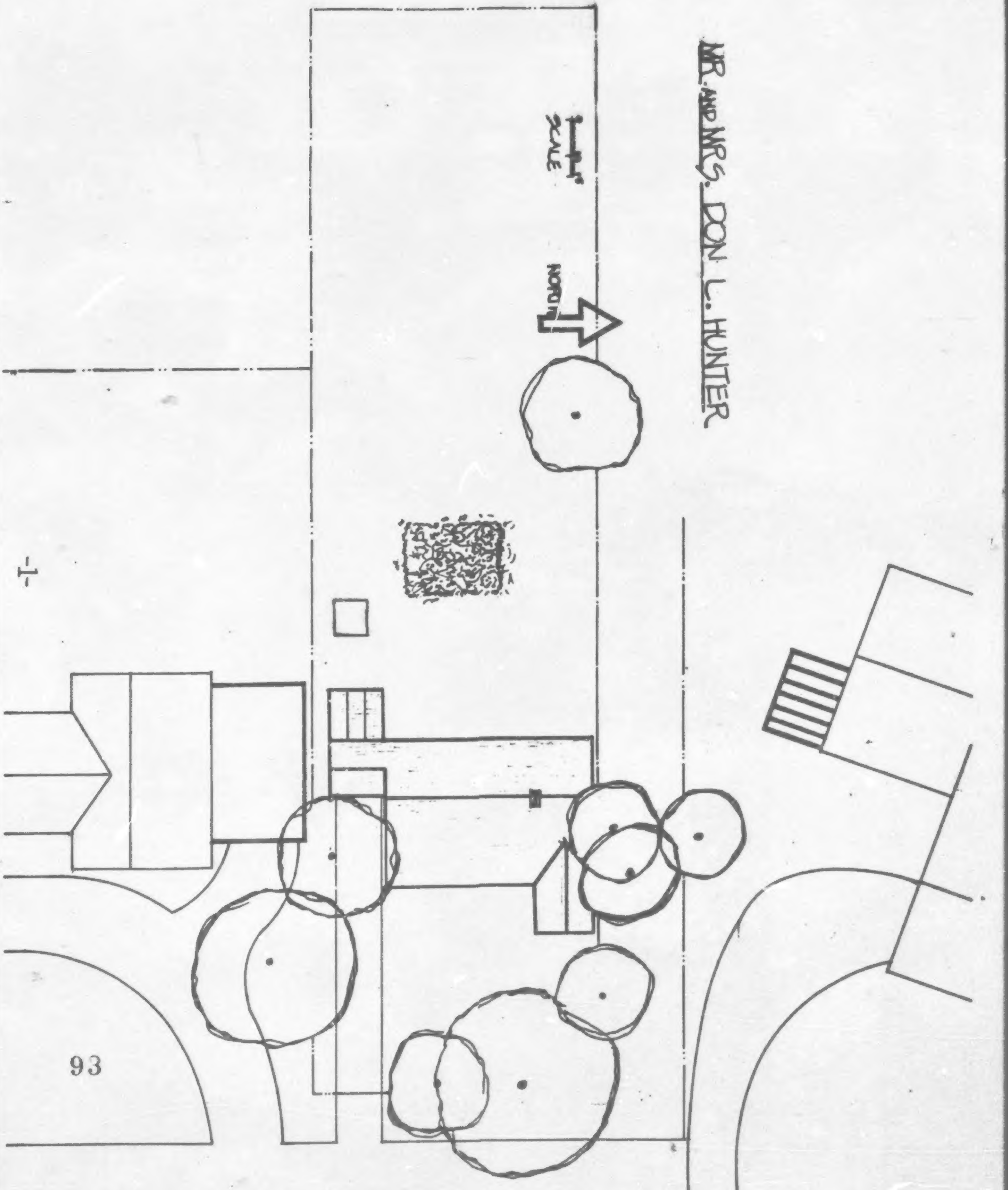
COMPARISON OF DEGREE DAYS RECORDED AND FUEL CONSUMPTION FOR THE SAME PERIOD.

ENERGY CONSUMPTION OF HIGGINS HOUSE, FROM EUGENE WATER AND ELECTRIC BOARD BILLS.

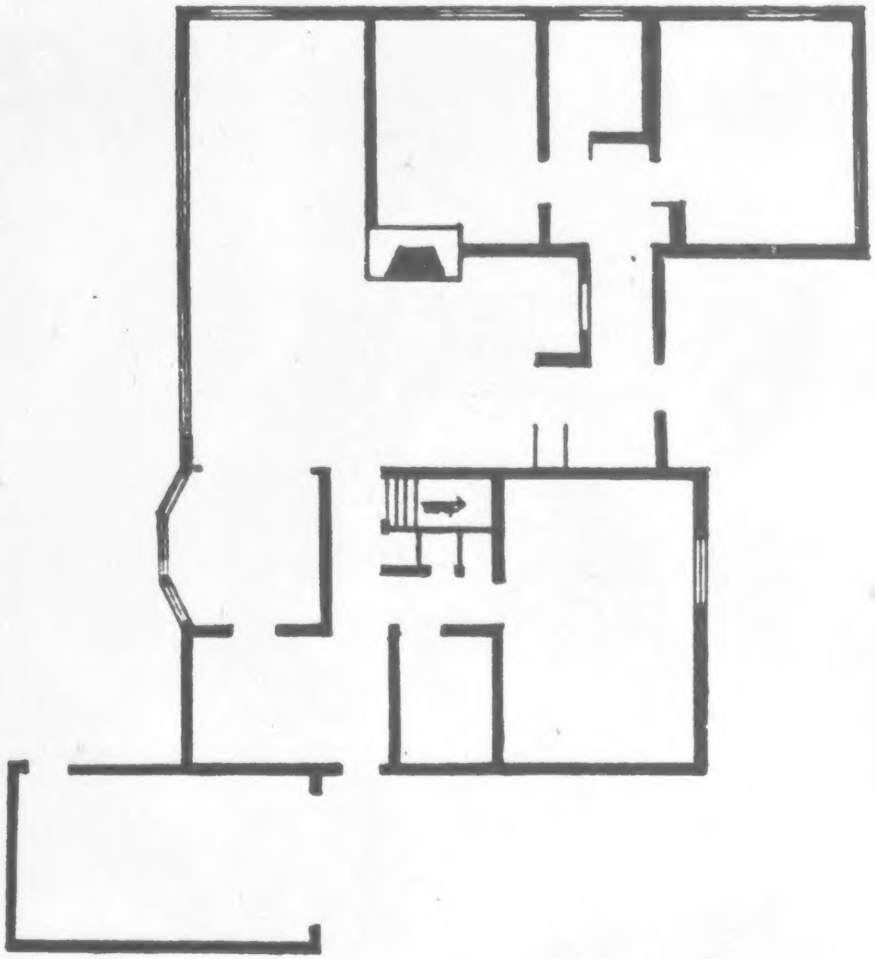
ACTUAL DEGREE DAYS. SOURCE IS THE LOCAL CLIMATOLOGICAL DATA FOR MAHLON SWEET AIRPORT, EUGENE. U.S. DEPT. COMMERCE, ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION.

PERIOD	USEAGE (KWH)	
SEPT 7/73 - OCT 9/73	1268	204
OCT 9/73 - NOV 21/73	4431	676
NOV 21/73 - DEC 24/73	4102	683
DEC 24/73 - JAN 25/74	5323	856
JAN 25/74 - FEB 26/74	4163	668
FEB 26/74 - MAR 27/74	2998	457
MAR 27-74 - APR 25/74	2509	372
APR 25/74 - MAY 24/74	1760	268
MAY 24/74 - JUNE 25/74	1083	117
JUNE 25/74 - JULY 25/74	950	43
JULY 25/74 - AUG 22/74	734	16
AUG 22/74 - SEPT 24/74	1005	4
SEPT 24/74 - OCT 24/74	1723	24
OCT 24/74 - NOV 23/74	3110	443

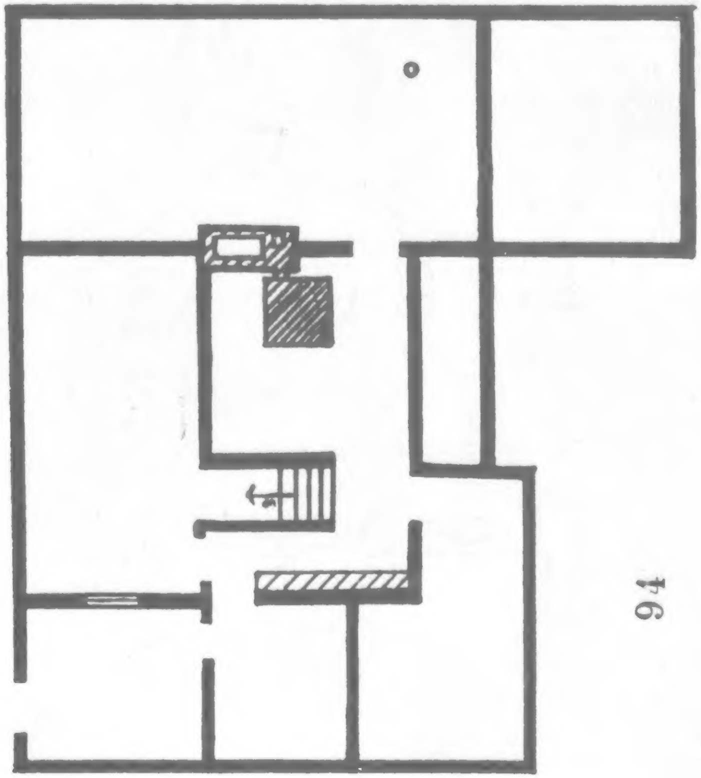



MR. AND MRS. DON L. HUNTER
SCALE
NORTH

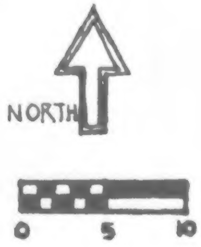
-1-



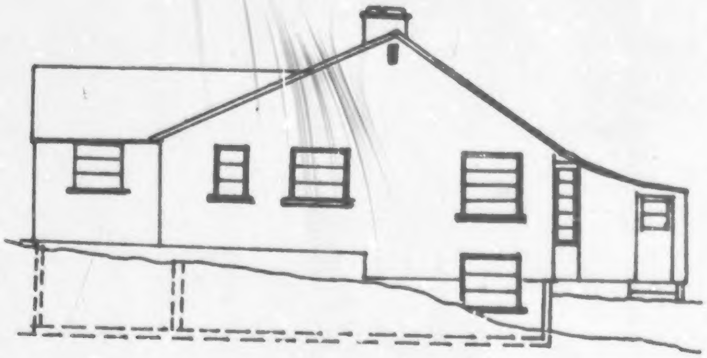
FIRST FLOOR PLAN



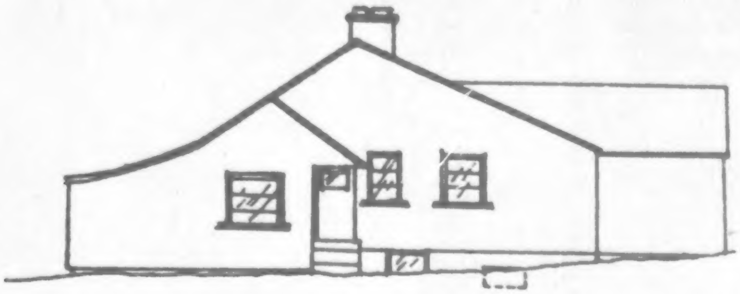
BASEMENT FLOOR PLAN



°THE HUNTERS -2-

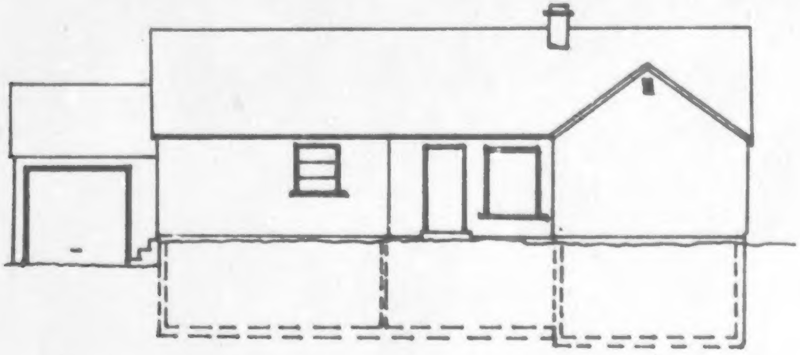


NORTH ELEVATION

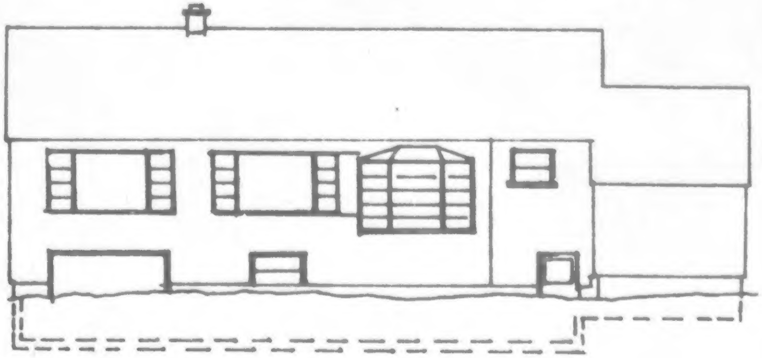


SOUTH ELEVATION

SCALE:



EAST ELEVATION



WEST ELEVATION

THE HUNTERS -3-

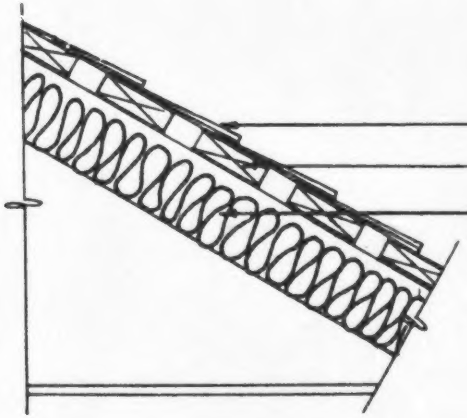
A personal interview is most helpful when determining the criteria for your solar retrofit. During this time, likes and dislikes as well as construction hints can be solicited for your design. This house was built by the owners father in 1939-40, and remodeled in 1950. The heating system is a sawdust burning, forced air, gravity fed system with a capacity of heating the house to 70 degrees during 0 degree weather. There is a large sawdust storage bin located in the southeast corner of the basement which stores green-clean sawdust year round. The sawdust burner heats the house comfortably to 70 degrees during the day and is turned down to 65 degrees at night.

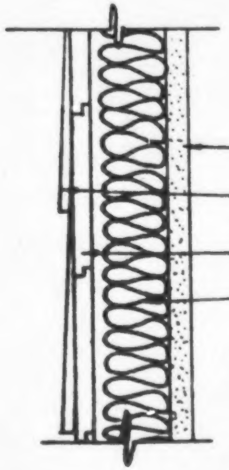
Because of the houses north-south ridge line, the ability of a roof collector without considerable change in the physical appearance was almost an impossibility. Because of the size of the family (2), the idea of an extension or additional construction was almost impossible. After further consultation, the desire for a picnic area with an arbor (for grapes, etc.) was given and therefore became a major portion of our design criteria.

Fortunately because of the large size lot (110 X 220) the collector had many possible locations. Because of our decision to build on the ground, alternative roof construction could be avoided. Also, because of the forced air system, direct use of the present heating system could be used.

The use of sawdust as a fuel is still a cheap heating agent as compared to our fossil fuels (in this area). Because of this, payoff times would appear to be too many years if the price and cost of heating were the only consideration. When looking at solar energy as a form of heat, of course, economic considerations are a big part but environmental issues can actually turn the tables in favor of solar. And wouldn't it be something to be the first on your block to have a working solar collector.

HEAT LOSS:





MATERIALS	"R"	"U" VALUES
GLASS(single strength)		1.13
PITCHED ROOF		
Wood Shingles		.07
Building Paper on 1"×4"		
3" Insulation		
FLOOR		2BTU/SF
BASEMENT WALL		4BTU/SF
WALL		
1" Plaster	.2	
Wood Shingles	1.19	
1"X8" Sheathing	.94	
3" Insulation	11.1	
	"R"= 13.43	.075
	(U=1/R)	

The Hunters maintain an inside temperature of 70, except at night.

ΔT= 70° Inside Temp. - 15° Outside Temp. = 55°

SURFACE AREAS		SF
ROOF		1650
WALL		1160
GLASS	upper	280
	lower	88
BASEMENT FLOOR		1500
BASEMENT WALL		1352

HEAT LOSS THROUGH SKIN BTUH = $A \cdot U \cdot \Delta T$

SURFACE	AREA	"U"	ΔT	BTUH
GLASS	368	1.13	55	22871
ROOF	1650	.07	55	6350
WALL	1160	.075	55	4785
BASEMENT		BTU/SF		
wall	1352	4		5400
floor	1500	2		3000
			TOTAL	42400

HEAT LOSS BY INFILTRATION

VOLUME	AIR CHANGE	ΔT	BTUH
1528(8)	.018	55	12100
		TOTAL HEAT LOSS	54500

Ave. House Loss= 1528(40)= 61120

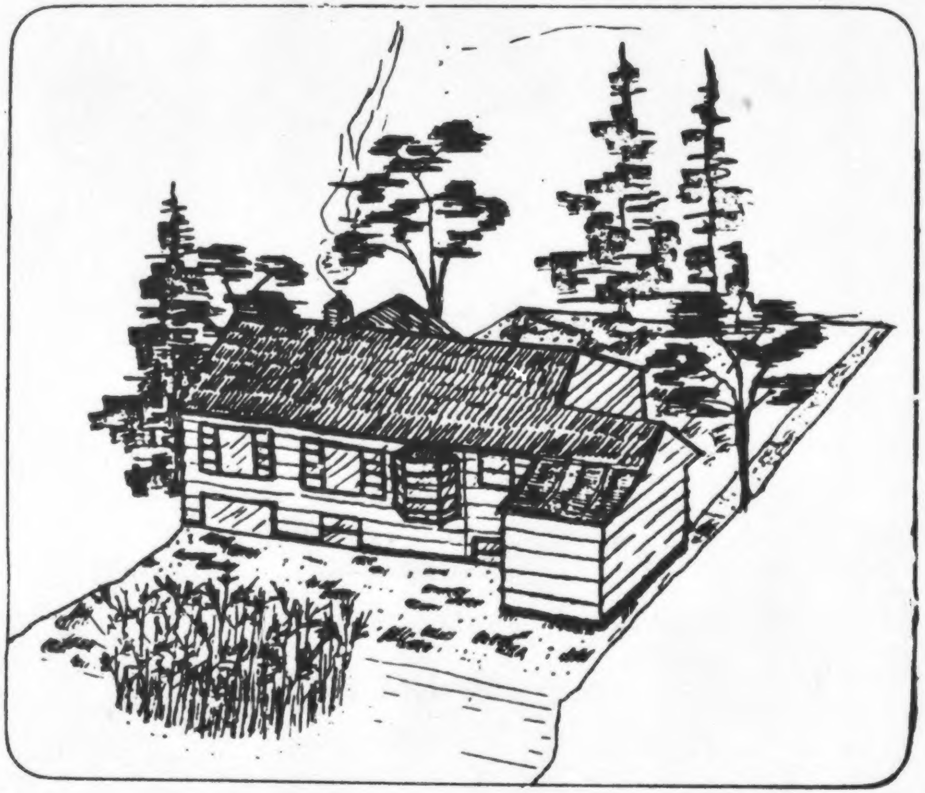
TOTAL HEAT LOSS /SF

54500/1528= 35.7 BTU/H/SF

The perspective on this page shows the house the way it looks today. The following show how the house will look with the varying alternatives. There are two items that are the same for all the alternatives. One is the use of a solar heated domestic water heater (which is a separate system) and the other is the placement and size of a storage tank. The water heater is described later.

As has been mentioned before, the basement has a sawdust storage bin and we propose to use half of the volume for a storage tank which will accomadate about 3500 gallon of water. It will be water proofed and insulated and made of reinforced concrete.

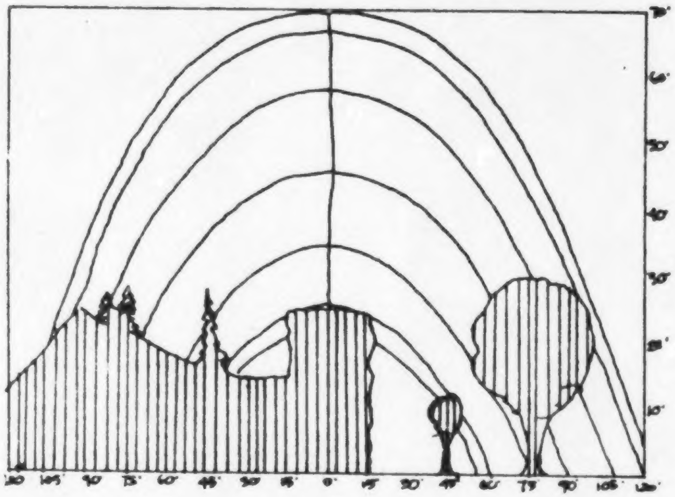
The storage tank size will be the same for all of the possible alternatives because as will be seen, the effective areas of the collectors is about equal.



THE HUNTERS -7-

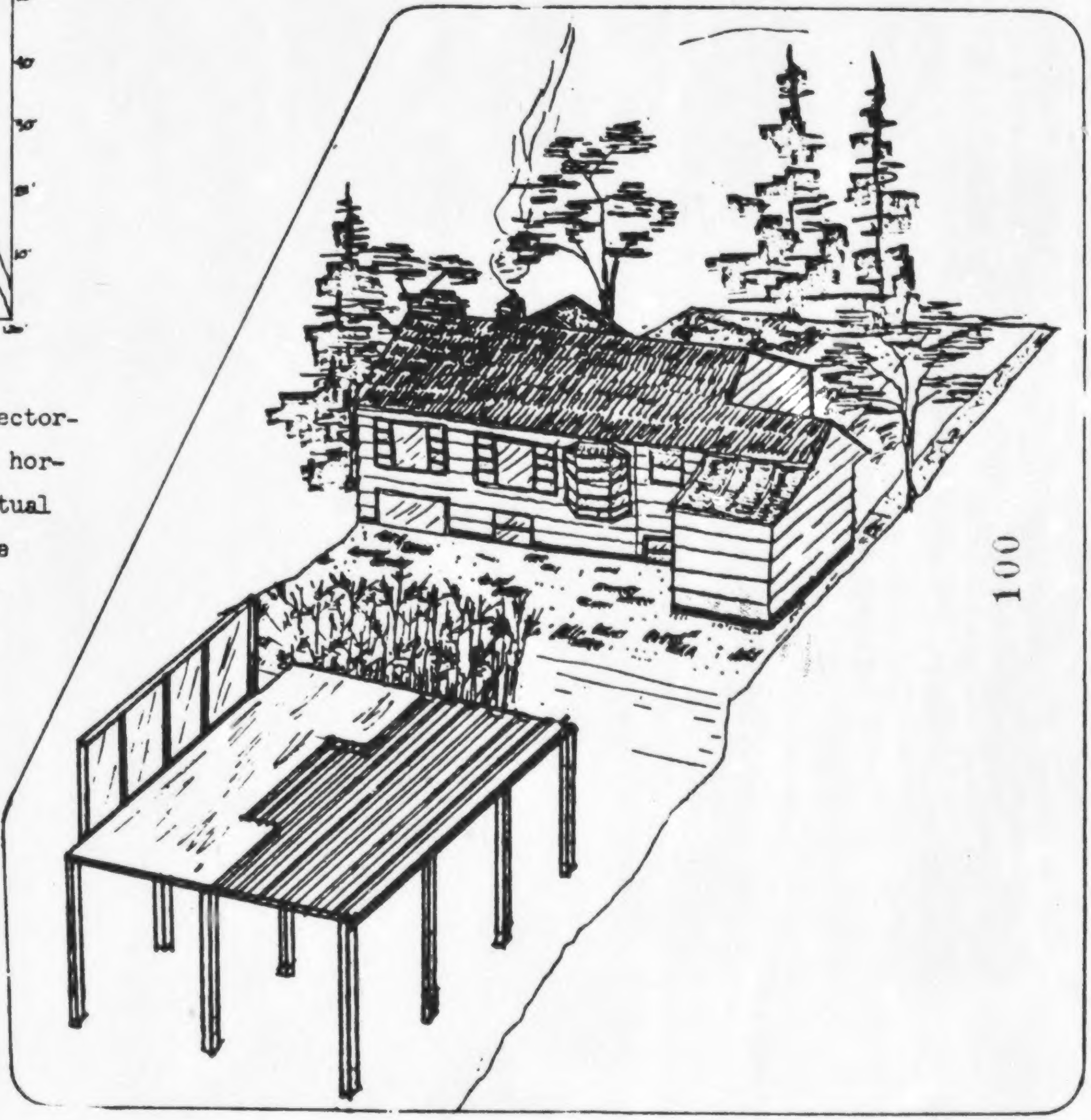
The cost for the storage tank and pump, piping and valves is considered in this study together to be one total expense because for each alternative it will be the same. For the Coos Bay house, a sum of nearly $5000 was alloted. For this particular project because the tank is less than half the size and the piping is not as extensive the assumed cost will be $3000.

ALTERNATIVE #1

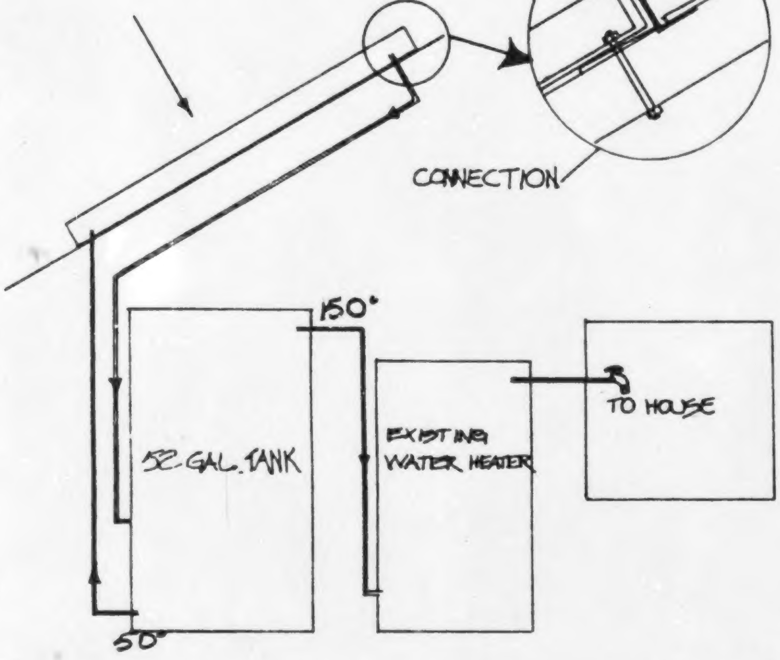


This alternative consists of a reflector-collector combination. The reflector is horizontal and collector, vertical. The actual area of collector is 200 SF, but with the use of an adequate reflector this can be doubled for the purposes of the collector performance. Extending the structure south, an arbor is offered with a sheltered picnic area beneath for protection from the summer sun.

Included with this alternative is a water heater. It is placed facing south on the east side of the house. A further analysis of the water heater and arbor-collector is found on the following two pages.



WATER HEATER:

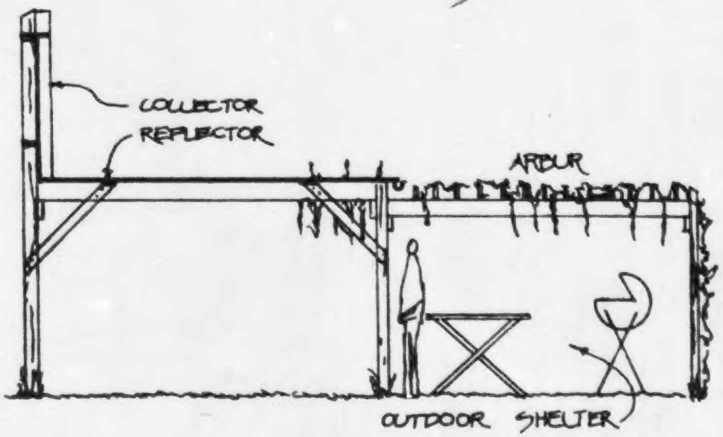

CONNECTION
150°
52 GAL. TANK
EXISTING WATER HEATER
TO HOUSE
50°

A complete water heater can be installed for about $700

The water heater is the most economical investment in solar energy because the intent is to supply 100% of the hot water needs of the house in the summer when insolation is the greatest. It is placed facing south on the east side of the house. 72Sq.Ft. will completely heat the water needs of the house between May and August but will help pre-heat the water for the rest of the year. It is sized using 1750 btu/SF at a 30 tilt and a 52 gal. pre-heat tank. MWEB supply water is 50, the water leaving the tank is 150.

ARBOR-COLLECTOR: also see adjoining page

The arbur-collector provides an outdoor eating place and a summer shelter which is something the Hunters have expressed a desire for. The storage tank is in the basement of the house occupying the lower part of the sawdust storage bin.


COLLECTOR
REFLECTOR
ARBUR
OUTDOOR SHELTER

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

Ⓘ. (T)(Area)(U) = g 54^{500} BTU/H

g 54^{500} BTU/H ÷ 1528 Floor Area = a 35.4 BTU/H/Ft²

II. a (___Factor)(______Floor Area) = g ______ BTU/H

'Conserving House' = 25 BTU/H/Ft²
'Typical House' = 40 BTU/H/Ft²

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (35.4 BTU/H/Ft²)(24 Hr.) = b 15.4 BTU/Degree Day/Ft²

(70 Inside Temp. - 15° Design Temp)

b (15.4 BTU/Degree Day/Ft²)(1528 Fl. Area)(21 Degree Days) = c 495^{000} BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

→ 395^{000} BTU/DAY

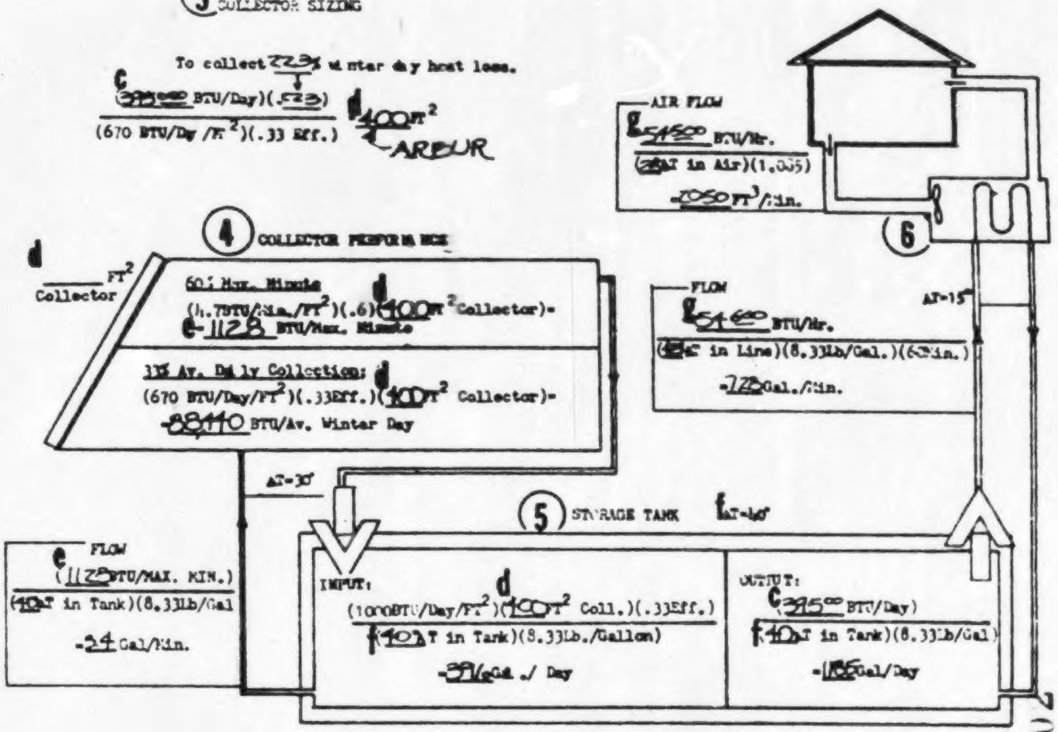
Insolation Data: (per Ft² of collector)
Max. Minute (100%) = 4.7 BTU/Min./Ft²
Av. Winter Day = 670 BTU/Day/Ft²
Max. Winter Day (100%) = 1000 BTU/Day/Ft²

③ COLLECTOR SIZING

To collect 22.3% winter day heat loss.

$$\frac{c\ (395000\ \text{BTU/Day})(.223)}{(670\ \text{BTU/Day}/\text{Ft}^2)(.33\ \text{Eff.})} = d\ 400\ \text{Ft}^2$$

ARBUR



60% Max. Minute

(4.7 BTU/Min./FT²)(.6)(d 400 FT² Collector) = e 1128 BTU/Max. Minute

33% Av. Daily Collection:

(670 BTU/Day/FT²)(.33 Eff.)(d 400 FT² Collector) = 88440 BTU/Av. Winter Day

FLOW

$$\frac{e\ (1125\ \text{BTU/MAX. MIN.})}{(40\Delta T\ \text{in Tank})(8.33\text{lb/Gal})} = 24\ \text{Gal/Min.}$$

INPUT:

$$\frac{(1000\text{BTU/Day/Ft}^2)(d\ 400\ \text{Ft}^2\ \text{Coll.})(.33\text{Eff.})}{f\ (40\Delta T\ \text{in Tank})(8.33\text{Lb./Gallon})} = 396\ \text{Gal./Day}$$

OUTPUT:

$$\frac{c\ (395^{00}\ \text{BTU/Day})}{f\ (40\Delta T\ \text{in Tank})(8.33\text{lb/Gal})} = 1186\ \text{Gal/Day}$$

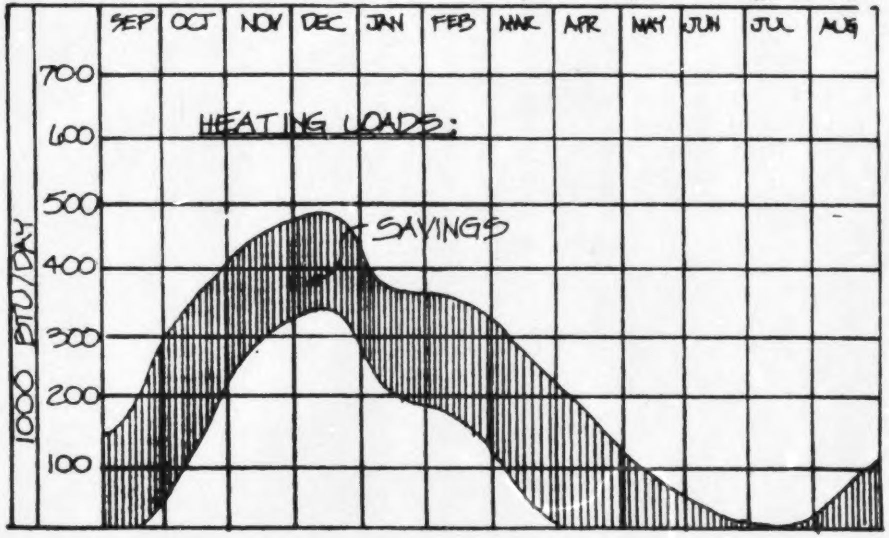
AIR FLOW

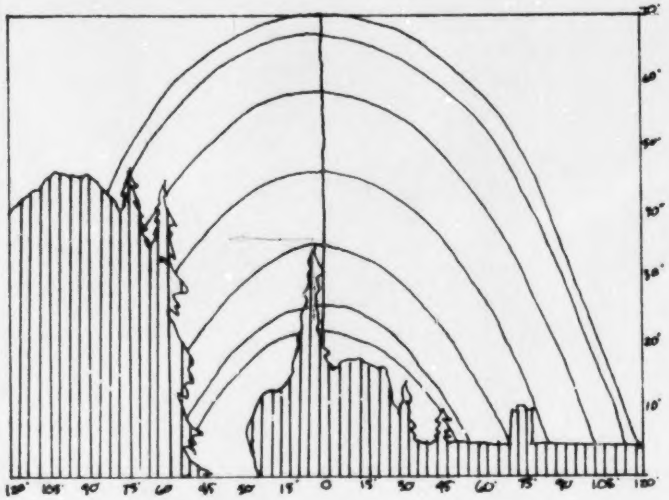
$$\frac{g\ 54500\ \text{BTU/Hr.}}{(25\Delta T\ \text{in Air})(1.085)} = 2050\ \text{FT}^3/\text{Min.}$$

FLOW

$$\frac{g\ 54600\ \text{BTU/Hr.}}{(52°F\ \text{in Line})(8.33\text{lb/Gal.})(60\ \text{Min.})} = 122\ \text{Gal./Min.}$$

COST:			
STRUCTURE	LABOR	MATERIAL	TOTAL
JOISTS 2×6 16"oc	\$220–	\$238–	\$458–
5/8" DECKING	\$167	\$320–	487
ROOFING	40	50	90
ALUM.	→	15	15
POST + BRACING	112	104	216
COLLECTOR			
STORAGE + PIPING			
	TOTAL		



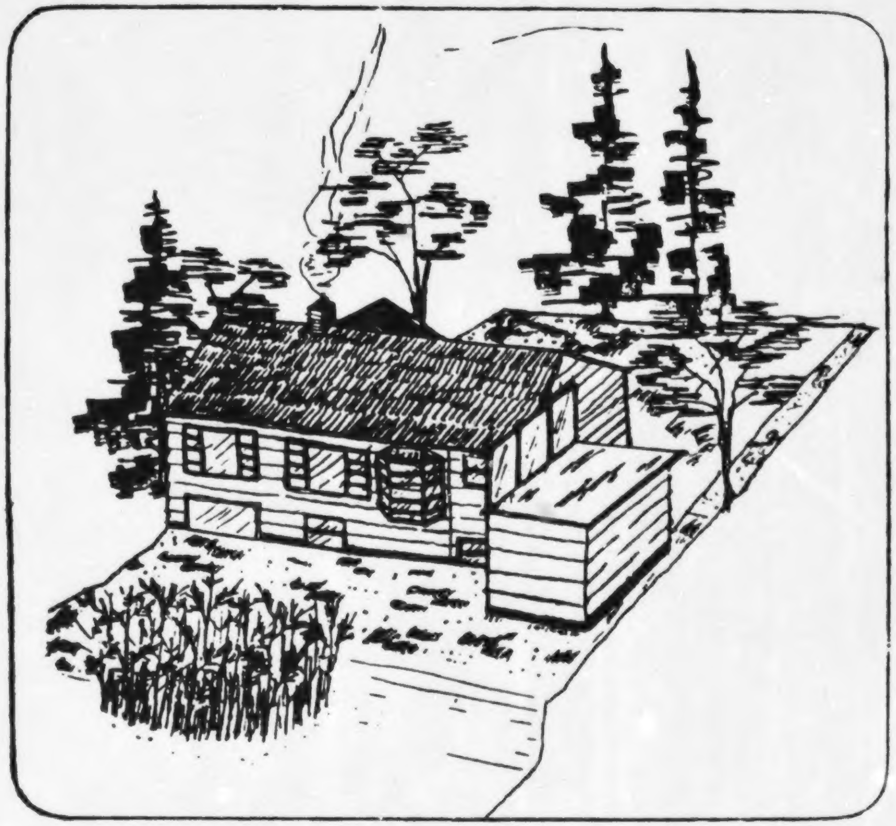


ALTERNATIVE #2

A water heater is included on the east roof and the study of it is the same as the preceeding pages.

For this alternative the garage roof is replaced with a flat reflector and vertical collector. The area of collector is 150 SF, but can be doubled because of the reflector. Being so close to the property line, this scheme relies greatly on the existing conditions to the south remaining the same. For some sites conditions could change and render the collector useless. However, for this neighborhood, the chance of a two story structure looming over the collector is highly unlikely.

The adjoining page includes, collector performance, heating loads and savings for the year, and a cost estimate.



Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (ΔT)(Area)(U) = g 54,000 BTU/H

g 54,000 BTU/H ÷ 1528 Floor Area = a 35.4 BTU/H/Ft²

II. a (35.4 Factor)(1528 Floor Area) = g 54,000 BTU/H

'Conserving House' = 25 BTU/H/Ft²
'Typical House' = 40 BTU/H/Ft²

② Heat Loss (BTU/DAY)

Winter Degree Days-Av=21/Day

a (35.4 BTU/H/Ft²)(24 Hr.) .= b 15.4 BTU/Degree Day/Ft²

(70 Inside Temp. - 15° Design Temp)

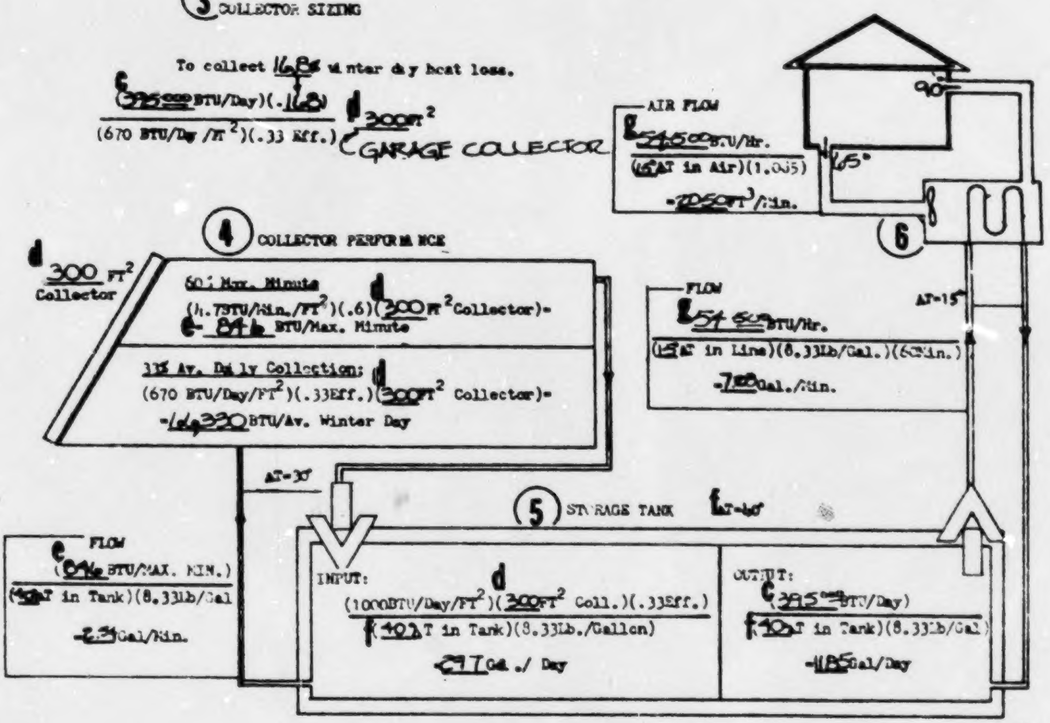
b (15.4 BTU/Degree Day/Ft²)(1528 Fl. Area)(21 Degree Days)= c 495,000 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

c 395,000 BTU/DAY

Insolation Data: (per Ft² of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft²
Av. Winter Day = 670 BTU/Day/Ft²
Max. Winter Day (100%) = 1000 BTU/Day/Ft²



③ COLLECTOR SIZING

To collect 16.8% winter day heat loss.

c (395,000 BTU/Day)(.168) / (670 BTU/Day /Ft²)(.33 Eff.) = d 300 Ft² GARAGE COLLECTOR

AIR FLOW

g 54,500 BTU/Hr. / (65 ΔT in Air)(1.085) = 2050 FT³/Min.

④ COLLECTOR PERFORMANCE

d 300 FT² Collector

60% Max. Minute

(4.7 BTU/Min./FT²)(.6)(d 300 FT² Collector)= e 846 BTU/Max. Minute

33% Av. Daily Collection:

(670 BTU/Day/FT²)(.33 Eff.)(d 300 FT² Collector)= 66,330 BTU/Av. Winter Day

FLOW

g 54,500 BTU/Hr. / (15 ΔT in Line)(8.33 Lb/Gal.)(60 Min.) = 7.00 Gal./Min.

FLOW

e (846 BTU/MAX. MIN.) / (40 ΔT in Tank)(8.33 lb/Gal = 2.54 Gal/Min.

⑤ STORAGE TANK f ΔT=40°

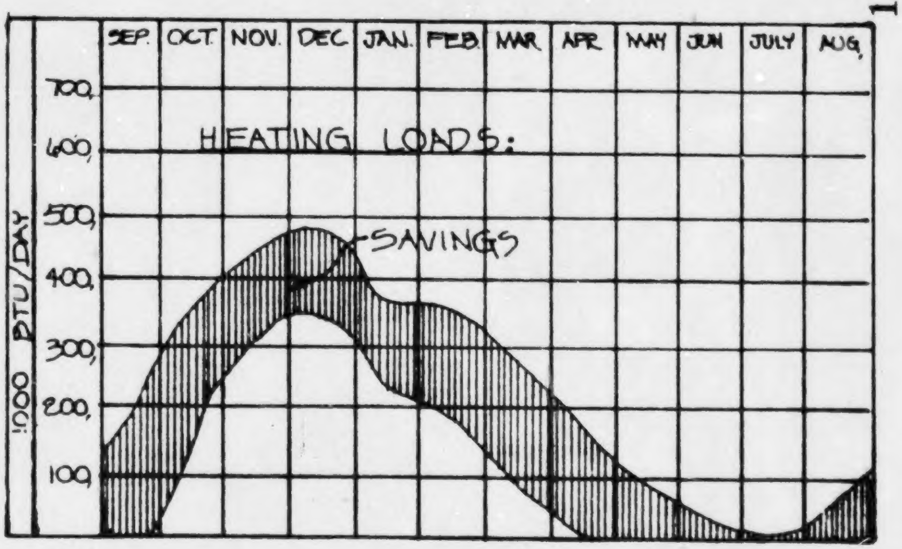
INPUT:

d (1000 BTU/Day/FT²)(300 FT² Coll.)(.33 Eff.) / f (40 ΔT in Tank)(8.33 Lb./Gallon) = 297 Gal./ Day

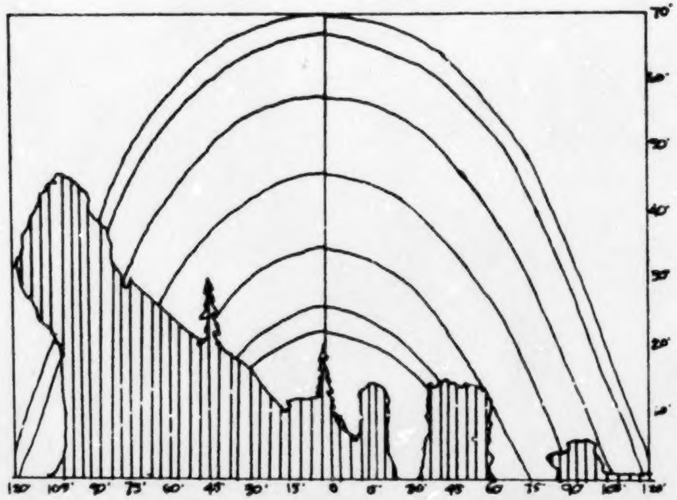
OUTPUT:

c (395,000 BTU/Day) / f (40 ΔT in Tank)(8.33 Lb/Gal) = 1185 Gal/Day

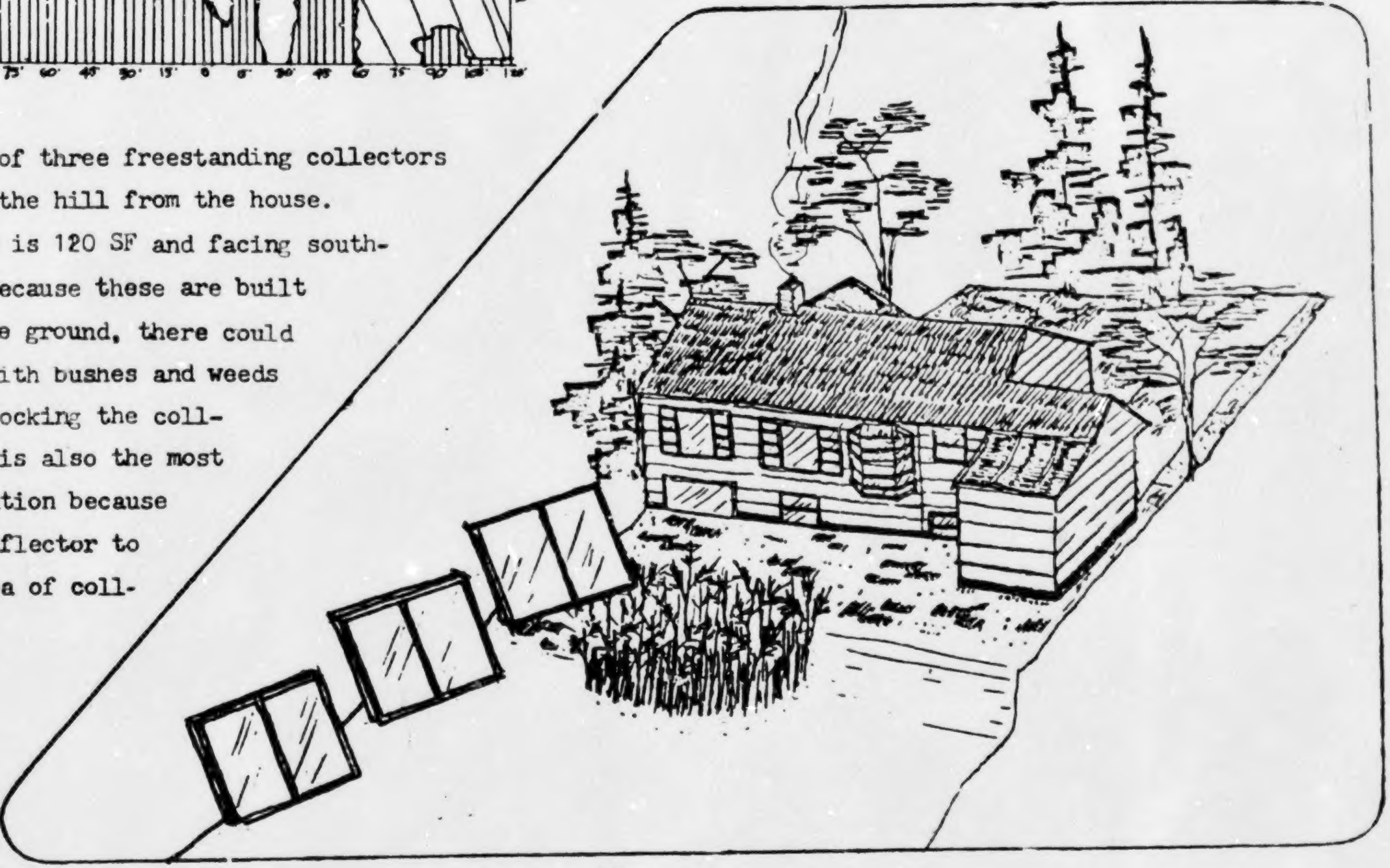
COST:			
STRUCTURE:	LABOR	MATERIALS	TOTAL
JOISTS 2x6" 16"OC	$63	$68.50	$132—
5/8" ROOF DECK	48	92.50	140—
ROOFING 15# FELT	5	8.50	14—
6 GAL. EMULSION	20	15.00	35—
ALUMINUM (REFLECTOR)	5	5.00	10—
COLLECTOR:			
2'x4' @ $65 (12)		780—	
OR $7.60/ft² (150ft²)		1140—	
STORAGE + PIPING			$3000
	TOTAL		$4,471



ALTERNATIVE #3



A "fence row" of three freestanding collectors run west down the hill from the house. Each collector is 120 SF and facing south-southwest. Because these are built directly on the ground, there could be a problem with bushes and weeds growing and blocking the collectors. This is also the most expensive solution because there is no reflector to reduce the area of collector needed.



Preliminary:

① Heat Loss (BTU/H)

Two Methods:

(I.) (T)(Area)(U) = g 54500 BTU/H

g 54500 BTU/H ÷ 1528 Floor Area = a 354 BTU/H/Ft^2

~~II.~~ a (___ Factor)(______ Floor Area) g ______ BTU/H

'Conserving House' = 25 BTU/H/Ft^2
'Typical House' = 40 BTU/H/Ft^2

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (354 BTU/H/Ft^2)(24 Hr.) = b 154 BTU/Degree Day/Ft^2

(70 Inside Temp. - 15° Design Temp)

b (154 BTU/Degree Day/Ft^2)(1528 Fl. Area)(21 Degree Days) = c 495000 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

395,000 BTU/DAY

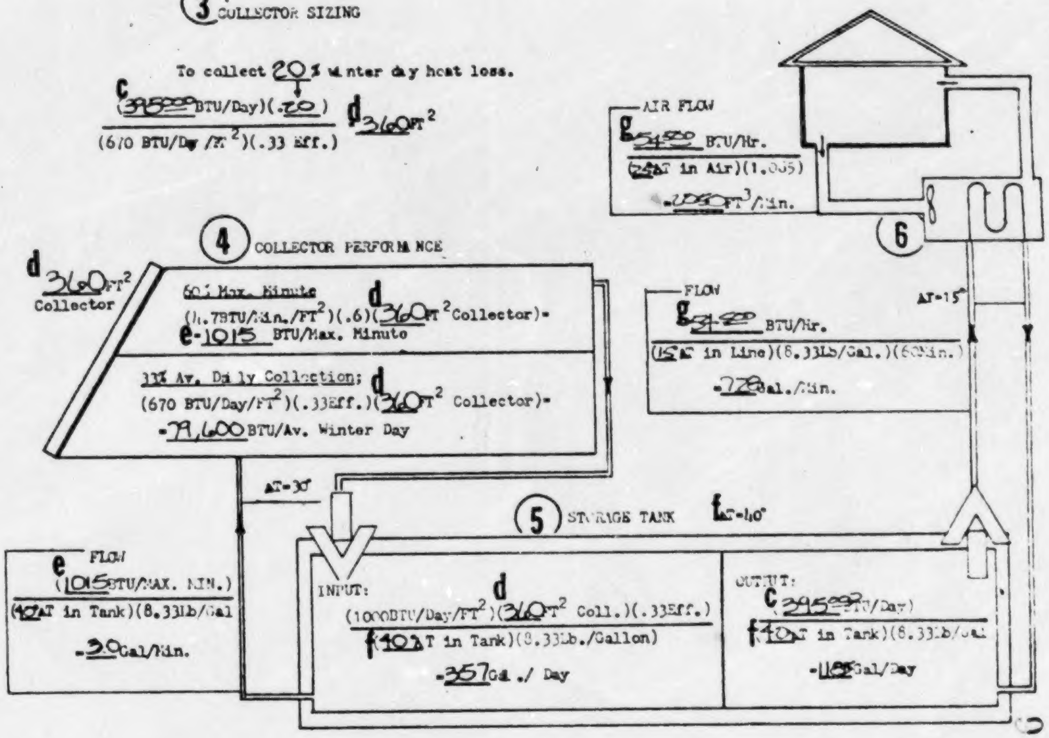
Insolation Data: (per Ft^2 of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft^2
Av. Winter Day = 670 BTU/Day/Ft^2
Max. Winter Day (100%) = 1000 BTU/Day/Ft^2

③ COLLECTOR SIZING

To collect 20% winter day heat loss.

$$\frac{c\,(395000\ \text{BTU/Day})(.20)}{(670\ \text{BTU/Day/FT}^2)(.33\ \text{Eff.})}\quad d\ 360\ \text{FT}^2$$



60% Max. Minute

(4.7BTU/Min./FT^2)(.6)(d 360 FT^2 Collector) = e 1015 BTU/Max. Minute

33% Av. Daily Collection;

(670 BTU/Day/FT^2)(.33Eff.)(d 360 FT^2 Collector) = 79,600 BTU/Av. Winter Day

AIR FLOW

$$\frac{g\ 54500\ \text{BTU/Hr.}}{(24\Delta T\ \text{in Air})(1.085)} = 2090\ \text{FT}^3/\text{Min.}$$

FLOW

$$\frac{g\ 54500\ \text{BTU/Hr.}}{(15\Delta T\ \text{in Line})(8.33\text{Lb/Gal.})(60\text{Min.})} = 728\ \text{Gal./Min.}$$

FLOW

$$\frac{e\ (1015\ \text{BTU/MAX. MIN.})}{(40\Delta T\ \text{in Tank})(8.33\text{lb/Gal})} = 3.0\ \text{Gal/Min.}$$

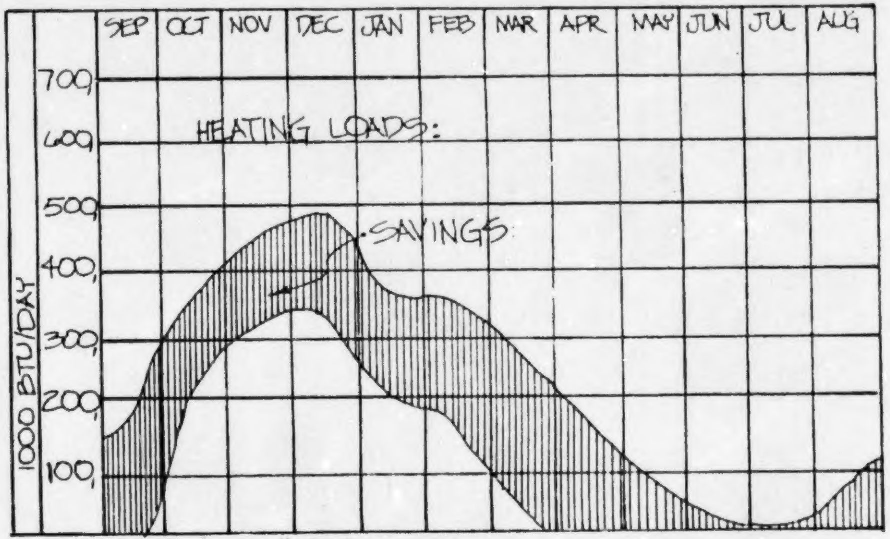
INPUT:

$$\frac{(1000\text{BTU/Day/FT}^2)(d\ 360\ \text{FT}^2\ \text{Coll.})(.33\text{Eff.})}{f\ (40\Delta T\ \text{in Tank})(8.33\text{Lb./Gallon})} = 357\ \text{Gal./Day}$$

OUTPUT:

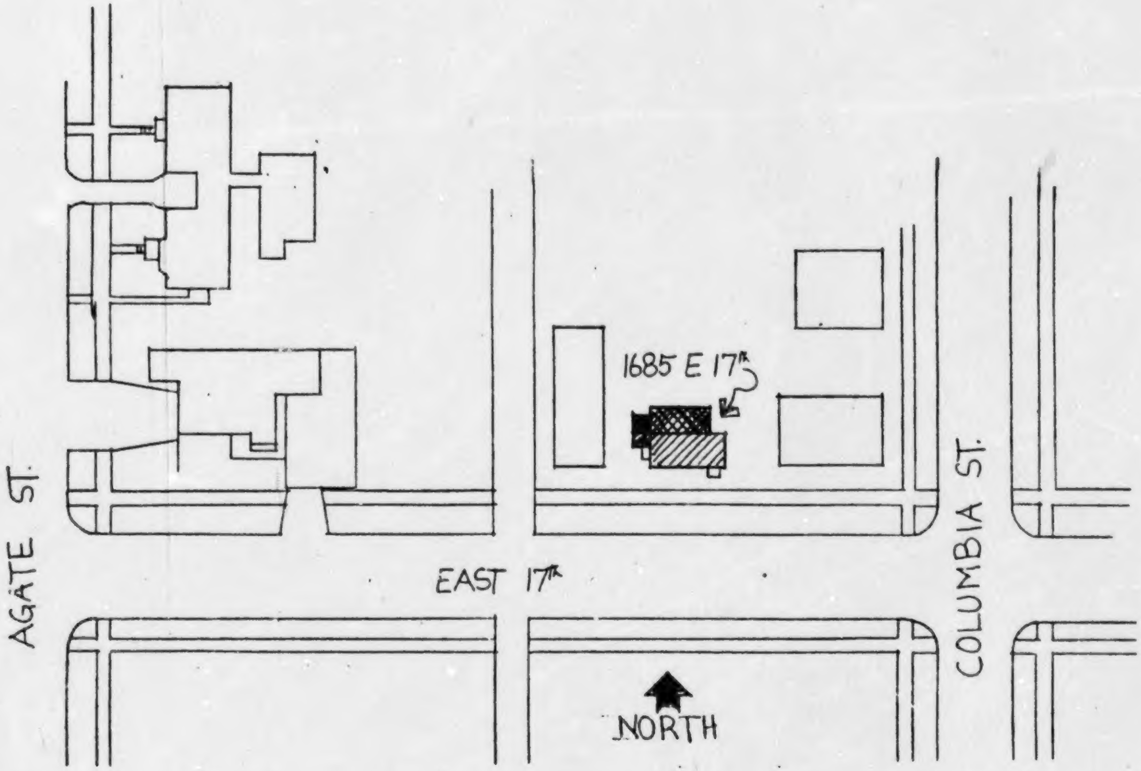
$$\frac{c\ (395000\ \text{BTU/Day})}{f\ (40\Delta T\ \text{in Tank})(8.33\text{Lb/Gal})} = 1185\ \text{Gal/Day}$$

COST			
STRUCTURE	LABOR	MATERIAL	TOTAL
TREATED 2x6 FRAME	$50	$100	$150
FOOTINGS (PIER)	$50	$25	$75
COLLECTOR		$2860	$2860
STORAGE AND PIPING			$3000
	TOTAL		$6085



A UNIVERSITY OWNED HOUSE:

1685 EAST 17TH STREET


AGATE ST.
1685 E 17th
EAST 17th
COLUMBIA ST.
NORTH

PHASING

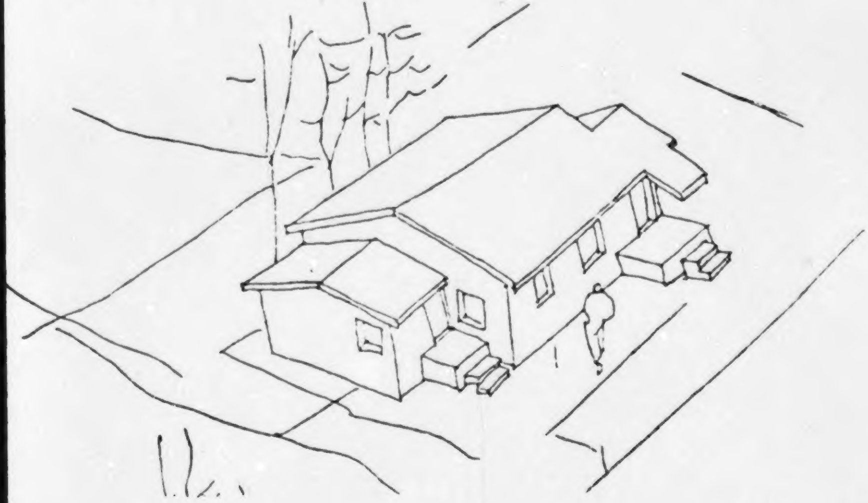
1.A New Addition:
The house itself was small, containing one bedroom. With the possibility of adding a solar collector, we incorporated the idea of combining a solar collector and an addition in one design. The high demand for housing within the University area is usually for a "couple", or more who will be using this house. By adding a second bedroom the user of the house has more flexability. Our major goal in this design was to combine the solar collector with the house and to make it aesthetically pleasing. The addition also would change other areas within the house: attic space, traffic patterns and spatial orientation.

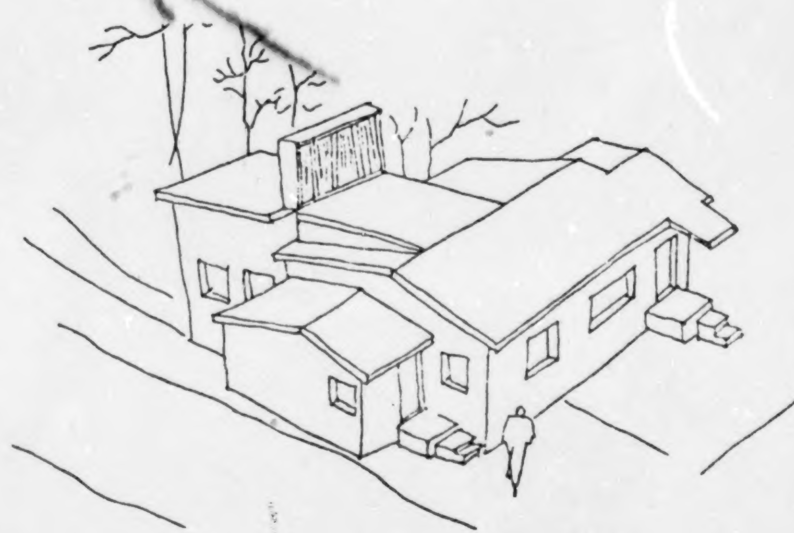
2.Double paned glass:
Another practical option was to install double paned windows. The heat loss by the single pained windows is the major source of heat loss. By installing the double pained windows, heat loss is cut nearly 50%.

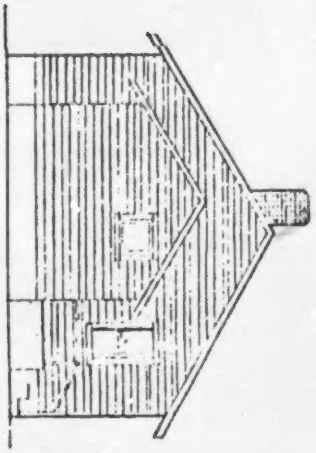
3.Roof insulation:
With the new addition to the house it was logical to change the north roof slope for the reflective surface. Because of this it became evident that with a little more effort thicker insulation might as well be installed to the rest of the roof. The existing insulation was 3" fiberglass- the new insulation is 5" fiberglass which cuts the heat loss of the entire house and leads to a smaller collector area.

4.New addition floor and walls:
The new addition's walls and floor have a better quality insulation to reduce heat loss.(The insulation is 5" cotton fiber)

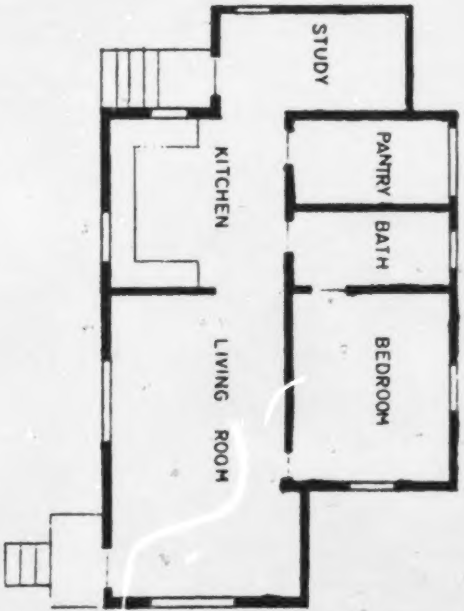
*Reasoning:
We felt all of these 4 phases are necessary before converting to solar.
The point to be made is, "Why go SOLAR if you are not conserving Energy" under present conditions.

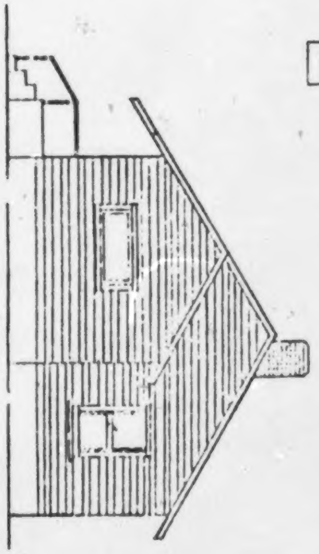




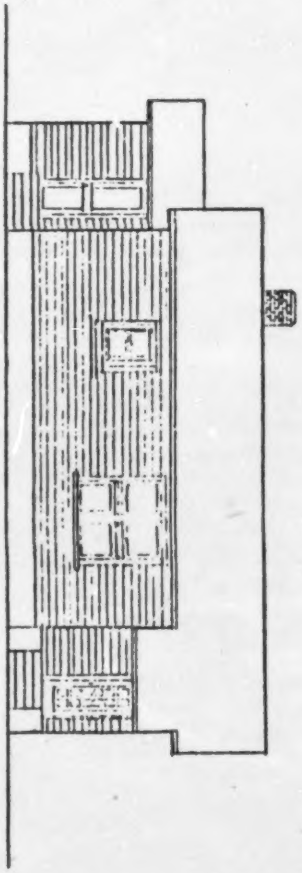


WEST ELEVATION

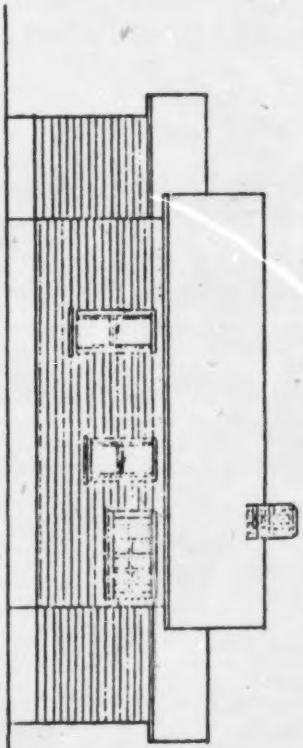

STUDY
PANTRY
KITCHEN
BATH
BEDROOM
LIVING ROOM



EAST ELEVATION

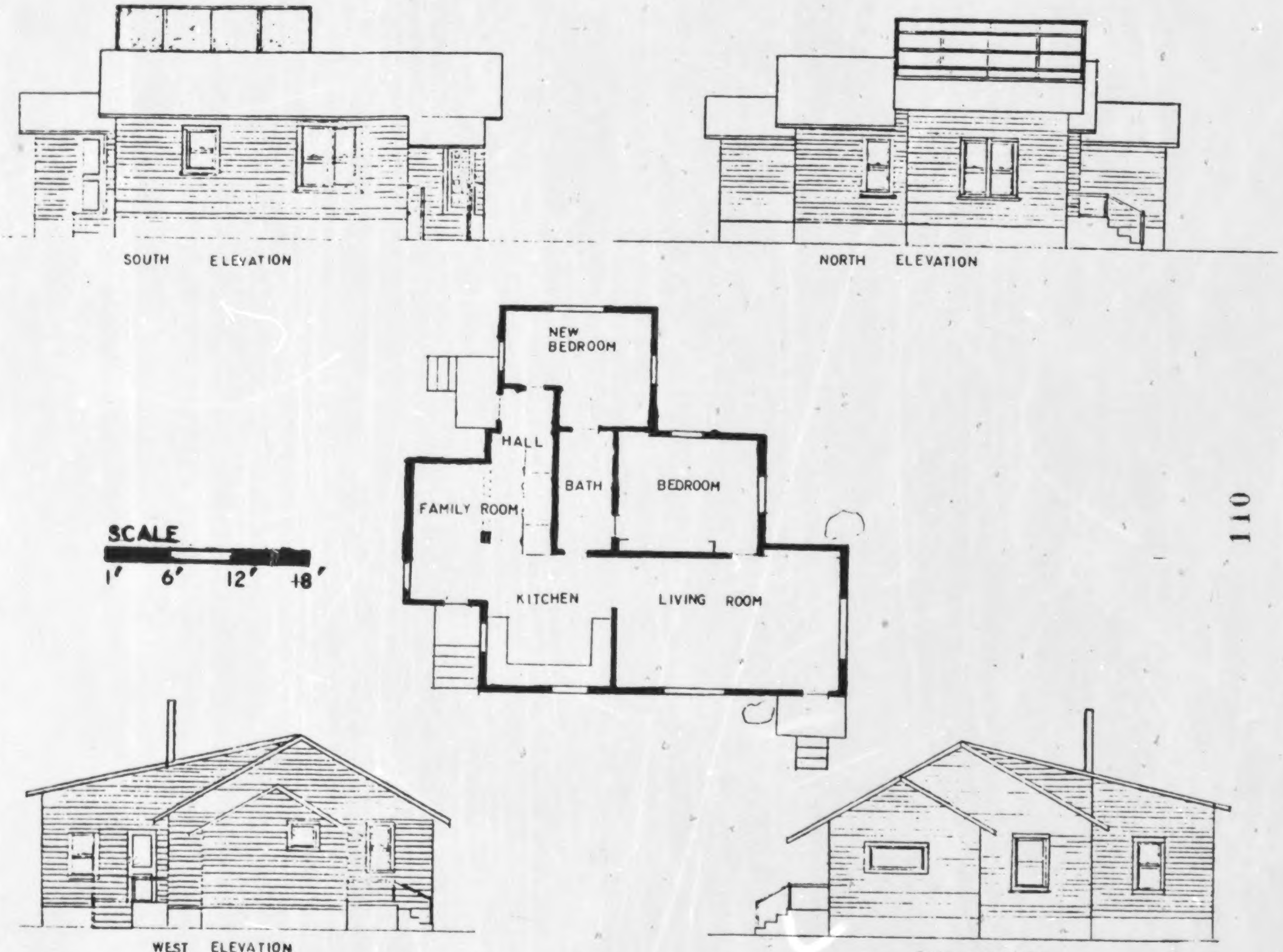


SOUTH ELEVATIC



NORTH ELEVATION

1685 E 37TH -3-


SOUTH ELEVATION
NORTH ELEVATION
NEW BEDROOM
HALL
BATH
BEDROOM
FAMILY ROOM
KITCHEN
LIVING ROOM
SCALE
1'
6'
12'
18'
WEST ELEVATION
EAST ELEVATION

1685 E 27TH -4-

BTUH LOSS AT PRESENT

HOUSE DATA

AREAS:
Floor Area = 798 Sq. Ft.
Roof Area = 798 Sq. Ft.
Insulated Wall = 925 Sq. Ft.
Glass Area = 135 Sq. Ft.

VOLUME = 7095 Cu. Ft.

DESIGN TEMPRATURE

For surfaces facing the exterior
$\Delta T = 65° - 15° = 50°$
For floor facing into crawl space
$\Delta T = 65° - 30° = 35°$
For roof facing into attic space
$\Delta T = 65° - 30° = 35°$

HEAT LOSS CALCULATIONS:

ROOF:

Area = 798 Sq. Ft.	"R"
3" fiber glass insulation	3.6 x 3 = 10.8
1" wood deck	3.28 3 = 1.06
Outside air film	.17 = .17
Inside air film	,68 x 3= 2.04
Total	= 14.07

$"U" = \frac{1}{14.07} = 0.071$

Heat loss = area x U x ΔT
= 798 x .071 x 35 = 1984 BTUH.

INSULATED WALL:

Area = 925 Sq. Ft.	"R"
½" wood siding	0.45
½" interior plywood	0.62
½" exterior plywood	0.62
3" insulation (fiber glass)	10.8
Inside air film	0.68
Outside air film	0.17
Total	= 13.34

$"U" = \frac{1}{13.34} = .0749$

Heat loss = area x U x ΔT
= 925 x .0749 x 50 = 3465 BTUH

GLASS:
Single pa.ned wood frame = 135 x 50 x 1.13 = 7628 BTUH

TOTAL SKIN LOSS:
Roof = 1984 BTUH   Glass = 7628 BTUH
Floor= 2302 BTUH   Wall = 3465 BTUH
Total = 15379 BTUH

BEFORE
AFTER

FLOOR:
Hardwood floor area = 602 Sq. Ft.
Linoleum floor area = 196 Sq. Ft.

	"R"
3" fiber glass insulation	10.8
½" Oak hardwood finish	45
¾" Wood (2)	1.18
Total	= 12.43

$"U" = \frac{1}{12.43} = .0804$

Heat loss hardwood floor
602 x 35 x .0804 = 1695 BTUH

Linoleum floor	0.05
3" insulation	10.8
¾" Wood (2)	1.18
Toaal =	11.31

$"U" = \frac{1}{11.31} = .0884$

Heat loss Linoleum floor: 196 x 35 x .0884 = 607 BTUH

LUNG LOSS:
Lung loss = .018 x T x Volume
= .018 x 50 x 7095 = 6386 BTU/Day

1 AIR CHANGE PER HOUR

BTUH LOSS PROPOSED

HOUSE DATA

FLOOR:

Area	= 798 Sq. Ft.
Addition area	= 168 Sq. Ft.
Total	= 966 Sq. Ft.

ROOF:

Area	= 798 Sq. Ft.
Addition area	= 168 Sq. Ft.
Total	= 966 Sq. Ft.

INSULATED WALL:

Area	= 832 Sq. Ft.
Addition area	= 269 Sq. Ft.

GLASS:

Area	= 100 Sq. Ft.
Addition area	= 50 Sq. Ft.

VOLUME OF HOUSE:

Whole house	= 8607 Cu. Ft.

DESIGN TEMPRATURE:

For surfaces facing the exterior
ΔT = 65° - 15° = 50°
For floor facing into crawl space
ΔT = 65° - 30° = 35°
For roof facing into attic space
ΔT = 65° - 30° = 35°

HEAT LOSS CALCULATIONS:

ROOF:

Existing roof heat loss:	"R"
5" fiber glass insulation	18.0
1" Wood deck	1.06
Outside air film	.17
Inside air film	2.04
Total	21.27
"U"	.047

Heat loss = Area x ΔT x U
=798 x 35 x .047
= 1312 BTUH

Addition roof heat loss:	"R"
5" polystrene insulation	19.25
1½" insul. wood deck	4.17
Outside air film	.17
Inside air film	2.04
Total	25.63
"U"	.039

Heat loss = 168 x 35 x.039
= 1541 BTUH

INSULATED WALL:

Existing wall Heat loss:	"R"
½" wood siding	.45
½" interior plywood	.62
½" exterior plywood	.62
3" fiber glass insulation	10.8
Outside air film	.17
Inside air film	.68
Total	13.34
"U"	.0749

Heat loss = 832 x 50 x .0749
= 3116 BTUH

Addition wall Heat loss:	"R"
5" cotton fiber insul.	19.25
1" softwood siding	1.25
1" softwood ext. siding	1.25
1" softwood int. siding	1.25
Outside air film	.17
Inside air film	.68
Total	23.85
"U"	.041

Heat loss = 269 x 50 x .041
= 551 BTUH

FLOOR:

	"R"
3" fiber glass insulation	10.8
½" Oak hardwood finish	.45
¾" wood (2)	1.18
Total	12.43
"U"	.0804

Heat loss = 798 x 35 x .0804
= 2245 BTUH

Addition floor Heat loss:	"R"
5" fiber glass insulation	19.25
½" Oak hardwood finish	.45
¾" wood (2)	1.18
Total	20.88
"U"	.047

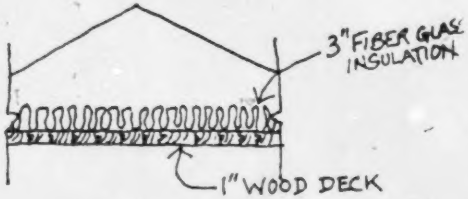
Heat loss = 168 x 35 x .047
= 276 BTUH

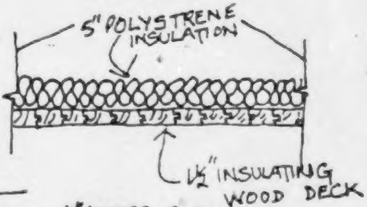
GLASS:

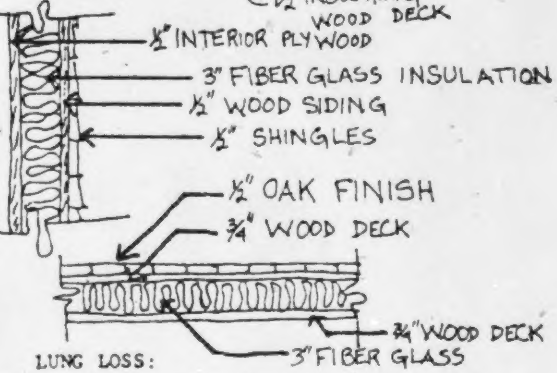
Double paned windows
Heat loss = 150 x 50 x .65
= 4875 BTUH

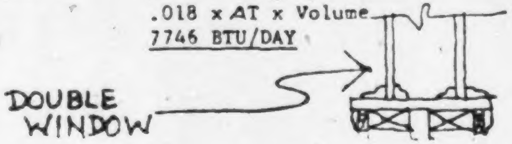
Total BTUH loss of house
12604 BTUH

LUNG LOSS:
1 Air Change per hour
.018 x ΔT x Volume
7746 BTU/DAY


3" FIBER GLASS INSULATION
1" WOOD DECK


5" POLYSTRENE INSULATION
1½" INSULATING WOOD DECK


½" INTERIOR PLYWOOD
3" FIBER GLASS INSULATION
½" WOOD SIDING
½" SHINGLES
½" OAK FINISH
¾" WOOD DECK
¾" WOOD DECK
3" FIBER GLASS


DOUBLE WINDOW

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (ΔT)(Area)(U) g 15379 BTU/H

g 15379 BTU/H÷ 798 Floor Area= a 20 BTU/H/Ft²

II. a 20 Factor)(798 Floor Area) g 15379 BTU/H

'Conserving House' = 25 BTU/H/Ft²
'Typical House' = 40 BTU/H/Ft²

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (20 BTU/H/Ft²)(24 Hr.) b 10 BTU/Degree Day/Ft²

(65 Inside Temp. - 15° Design Temp)

b (10 BTU/Degree Day/Ft²)(798 Fl. Area)(21 Degree Days)= c 167580 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

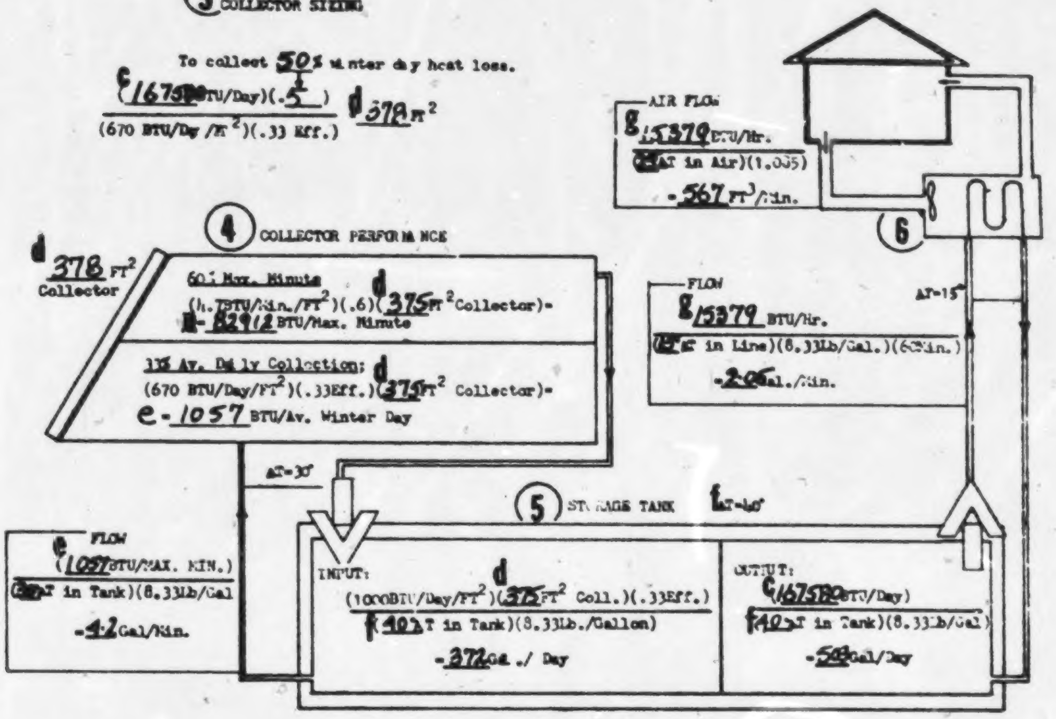
Insolation Data: (per Ft² of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft²
Av. Winter Day = 670 BTU/Day/Ft²
Max. Winter Day (100%)= 1000 BTU/Day/Ft²

③ COLLECTOR SIZING

To collect 50% winter day heat loss.

$$\frac{c\ (167580\ \text{BTU/Day})(.5)}{(670\ \text{BTU/Day/Ft}^2)(.33\ \text{Eff.})} = d\ 378\ \text{Ft}^2$$



d 378 FT² Collector

④ COLLECTOR PERFORMANCE

60% Max. Minute
(4.7BTU/Min./FT²)(.6)(d 375 FT² Collector)=
= 829.12 BTU/Max. Minute

33% Av. Daily Collection;
(670 BTU/Day/FT²)(.33Eff.)(d 375 FT² Collector)=
e = 1057 BTU/Av. Winter Day

AIR FLOW
$$\frac{g\ 15379\ \text{BTU/Hr.}}{(25\ \Delta T\ \text{in Air})(1.085)}$$
= 567 FT³/Min.

⑥

FLOW
$$\frac{g\ 15379\ \text{BTU/Hr.}}{(15\ \Delta T\ \text{in Line})(8.33\text{Lb/Gal.})(60\ \text{Min.})}$$
= 2.06 Gal./Min.

ΔT=15°

ΔT=30°

⑤ STORAGE TANK f ΔT=40°

FLOW
$$\frac{e\ (1057\ \text{BTU/MAX. MIN.})}{(30\ \Delta T\ \text{in Tank})(8.33\text{Lb/Gal})}$$
= 4.2 Gal/Min.

INPUT:
$$\frac{(1000\text{BTU/Day/FT}^2)(d\ 375\ \text{FT}^2\ \text{Coll.})(.33\text{Eff.})}{f\ (40\ \Delta T\ \text{in Tank})(8.33\text{Lb./Gallon})}$$
= 372 Gal./ Day

OUTPUT:
$$\frac{c\ (167580\ \text{BTU/Day})}{f\ (40\ \Delta T\ \text{in Tank})(8.33\text{Lb/Gal})}$$
= 503 Gal/Day

-BEFORE→

-AFTER→

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (ΔT)(Area)(U)= g 12604 BTU/H

g 12604 BTU/H÷ 966 Floor Area= a 13 BTU/H/Ft^2

II. a (13 Factor)(966 Floor Area) g 12604 BTU/H

'Conserving House' = 25 BTU/H/Ft^2
'Typical House' = 40 BTU/H/Ft^2

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day

a (13 BTU/H/Ft^2)(24 Hr.) = b 6.24 BTU/Degree Day/Ft^2

(65° Inside Temp. - 15° Design Temp)

b (6.24 BTU/Degree Day/Ft^2)(966 Fl. Area)(21 Degree Days)= c 126584 BTU/DAY

Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

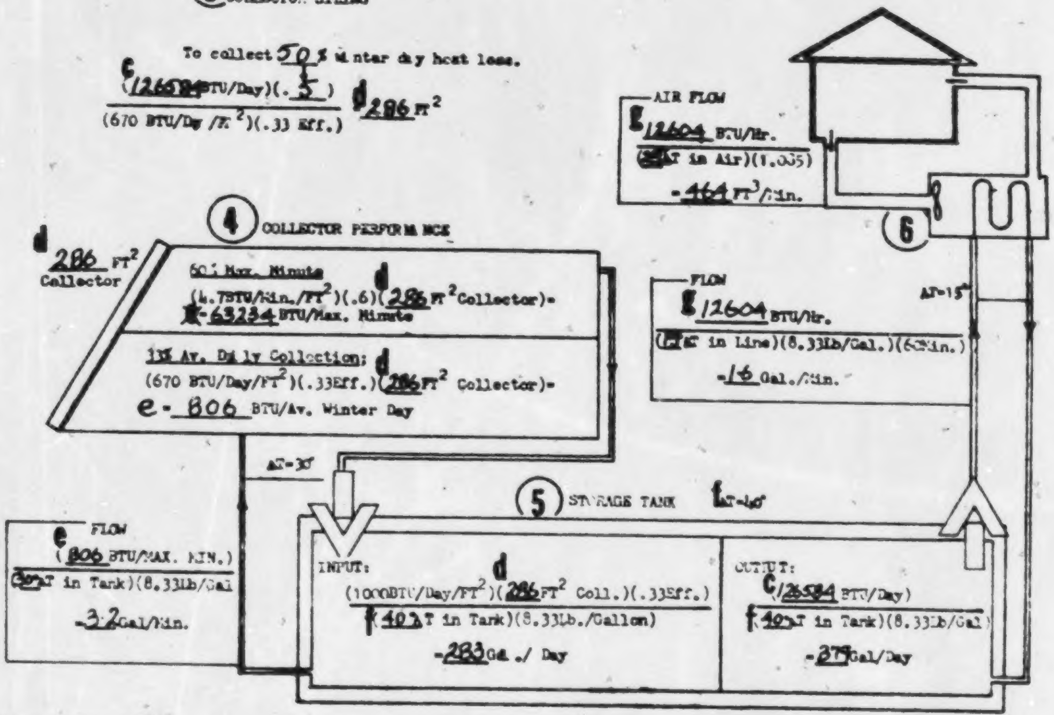
Insolation Data: (per Ft^2 of collector)

Max. Minute (100%) = 4.7 BTU/Min./Ft^2
Av. Winter Day = 670 BTU/Day/Ft^2
Max. Winter Day (100%)= 1000 BTU/Day/Ft^2

③ COLLECTOR SIZING

To collect 50 % winter day heat loss.

$$\frac{c\,(126584\ \text{BTU/Day})(.5)}{(670\ \text{BTU/Day}/\text{Ft}^2)(.33\ \text{Eff.})} = d\ 286\ \text{Ft}^2$$



④ COLLECTOR PERFORMANCE

d 286 FT^2 Collector

60% Max. Minute

(4.7BTU/Min./FT^2)(.6)(d 286 FT^2 Collector)= 63234 BTU/Max. Minute

33% Av. Daily Collection;

(670 BTU/Day/FT^2)(.33Eff.)(d 286 FT^2 Collector)= e 806 BTU/Av. Winter Day

ΔT=30°

FLOW

$$\frac{e\,(806\ \text{BTU/MAX. MIN.})}{(30\ \Delta T\ \text{in Tank})(8.33\text{Lb/Gal})} = 3.2\ \text{Gal/Min.}$$

⑤ STORAGE TANK

f ΔT=40°

INPUT:

$$\frac{(1000\text{BTU/Day/FT}^2)(d\ 286\ \text{FT}^2\ \text{Coll.})(.33\text{Eff.})}{f\,(40\ \Delta T\ \text{in Tank})(8.33\text{Lb./Gallon})} = 283\ \text{Gal./Day}$$

OUTPUT:

$$\frac{c\,(126584\ \text{BTU/Day})}{f\,(40\ \Delta T\ \text{in Tank})(8.33\text{Lb/Gal})} = 379\ \text{Gal/Day}$$

⑥

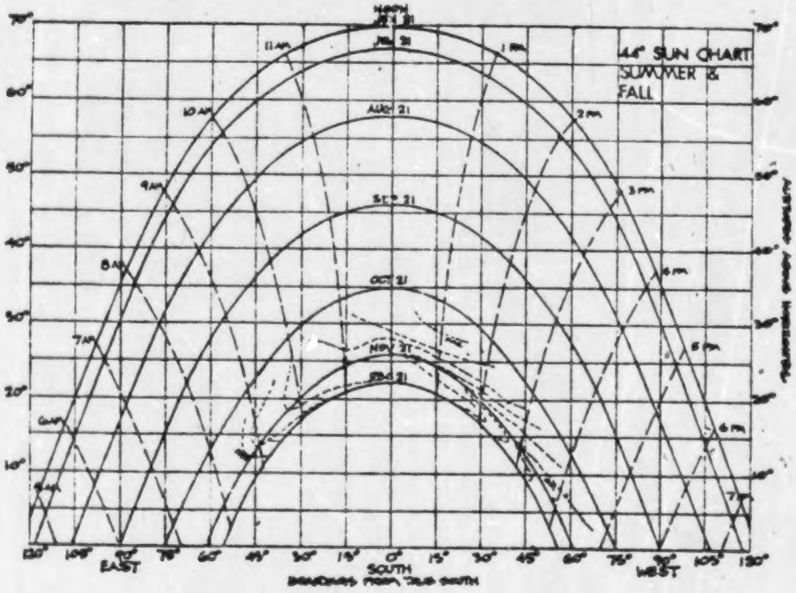
AIR FLOW

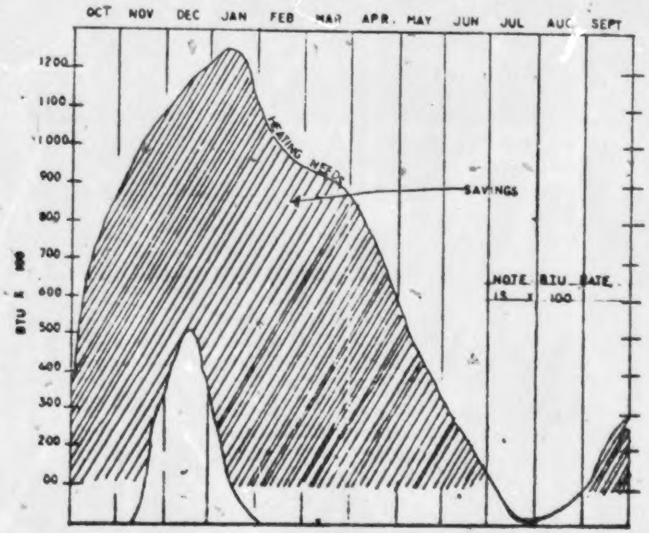
$$\frac{g\ 12604\ \text{BTU/Hr.}}{(20\ \Delta T\ \text{in Air})(1.085)} = 464\ \text{Ft}^3/\text{Min.}$$

ΔT=15°

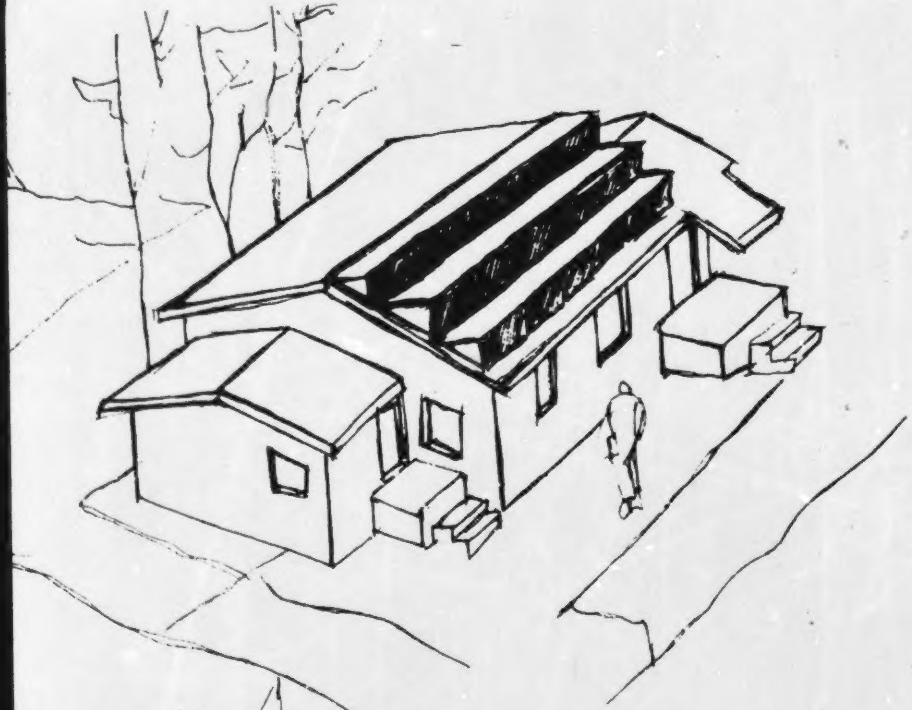
FLOW

$$\frac{g\ 12604\ \text{BTU/Hr.}}{(15\ \Delta T\ \text{in Line})(8.33\text{Lb/Gal.})(60\text{Min.})} = 1.6\ \text{Gal./Min.}$$

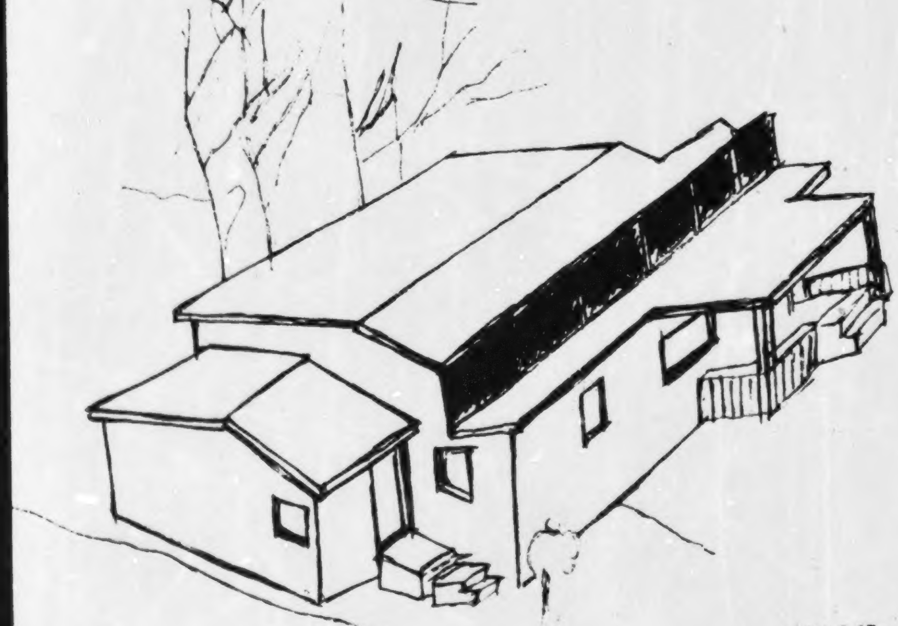




OPTIONS



Option 1 A series of reflector - collector "steps" on the south facing roof is a way to retrofit this house without increasing the current floor area. (Running perpendicular to the ground would be the collector while the reflectors would be parallel to the ground.) This alternative would make good use of the existing structure without having to alter the house significantly. (See sketch)



Option 2 Another alternative would be to retrofit the house with the addition of a covered porch to the main entry. The retrofitting would involve cutting into the existing roof-line and installing the collector into the cut. Perpendicular to this would be the reflector - giving the house a flat roof in front.

This porch addition is typical to many of the houses in this area. It is also a place for the residents to sit, relax and talk to the neighbors along with adding protection from the weather.

1685 E 17TH

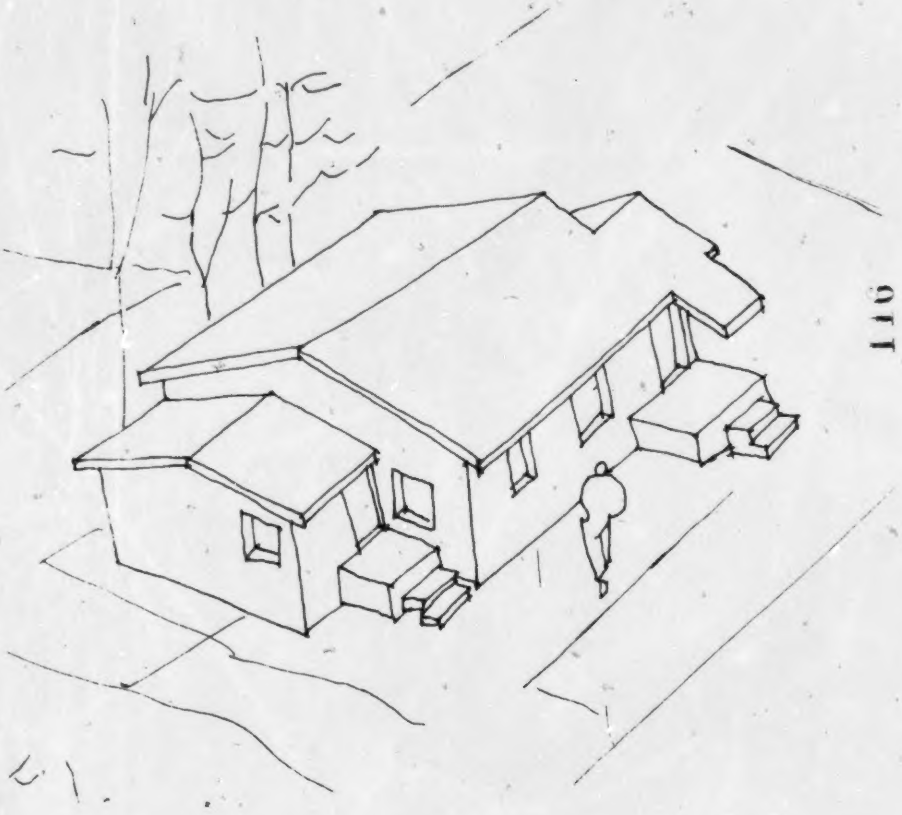
CONCLUSION

The house on the right is a "typical" house. Like so many other American homes in the Pacific Northwest, it is losing a great deal of heat under its present condition. Conservation measures such as cutting down the degree of room temperature, adding storm windows, installing double paned glass and increasing the insulation, should all be considered before any retrofitting takes place in this house. (The data on the previous pages show what a big difference these measures can make.)

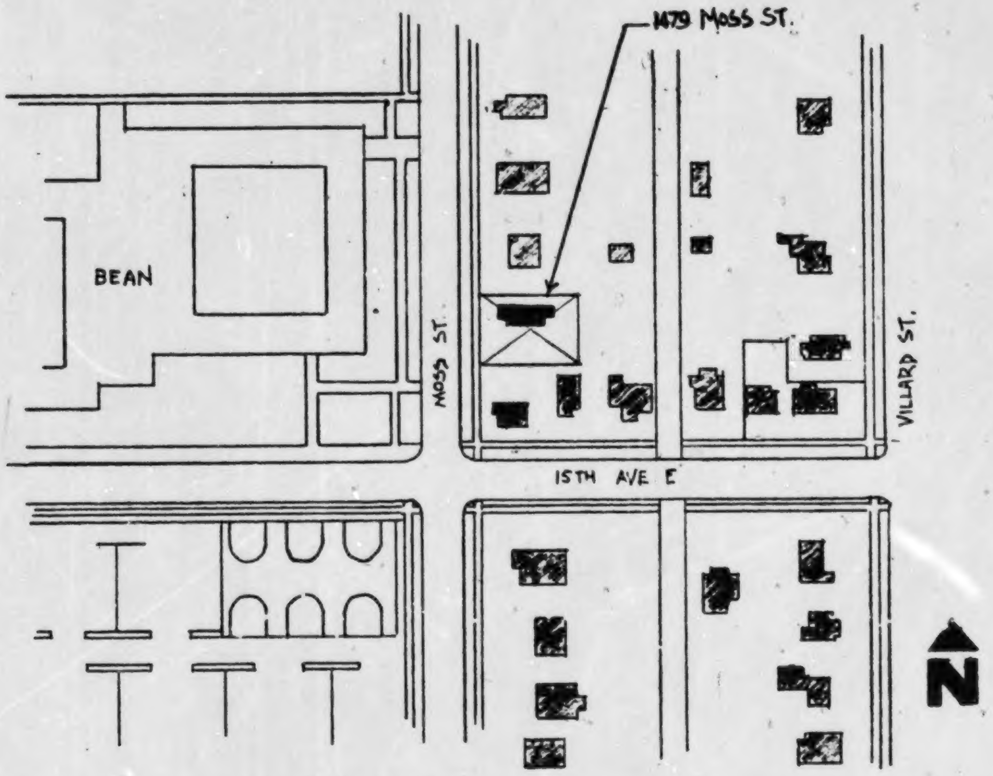
We chose to study this house because it was typical in many ways: size, shape and orientation to its neighbors. Several retrofitting alternatives were studied with the idea of a bedroom addition getting the most attention. (Incorporated in this was a spatial study of the house and its owners needs.)

The solutions and options presented here were by no means the only alternatives. With a limited time factor it was soon realized that this project can only act as a small glimpse as to how to retrofit a house of this scale.

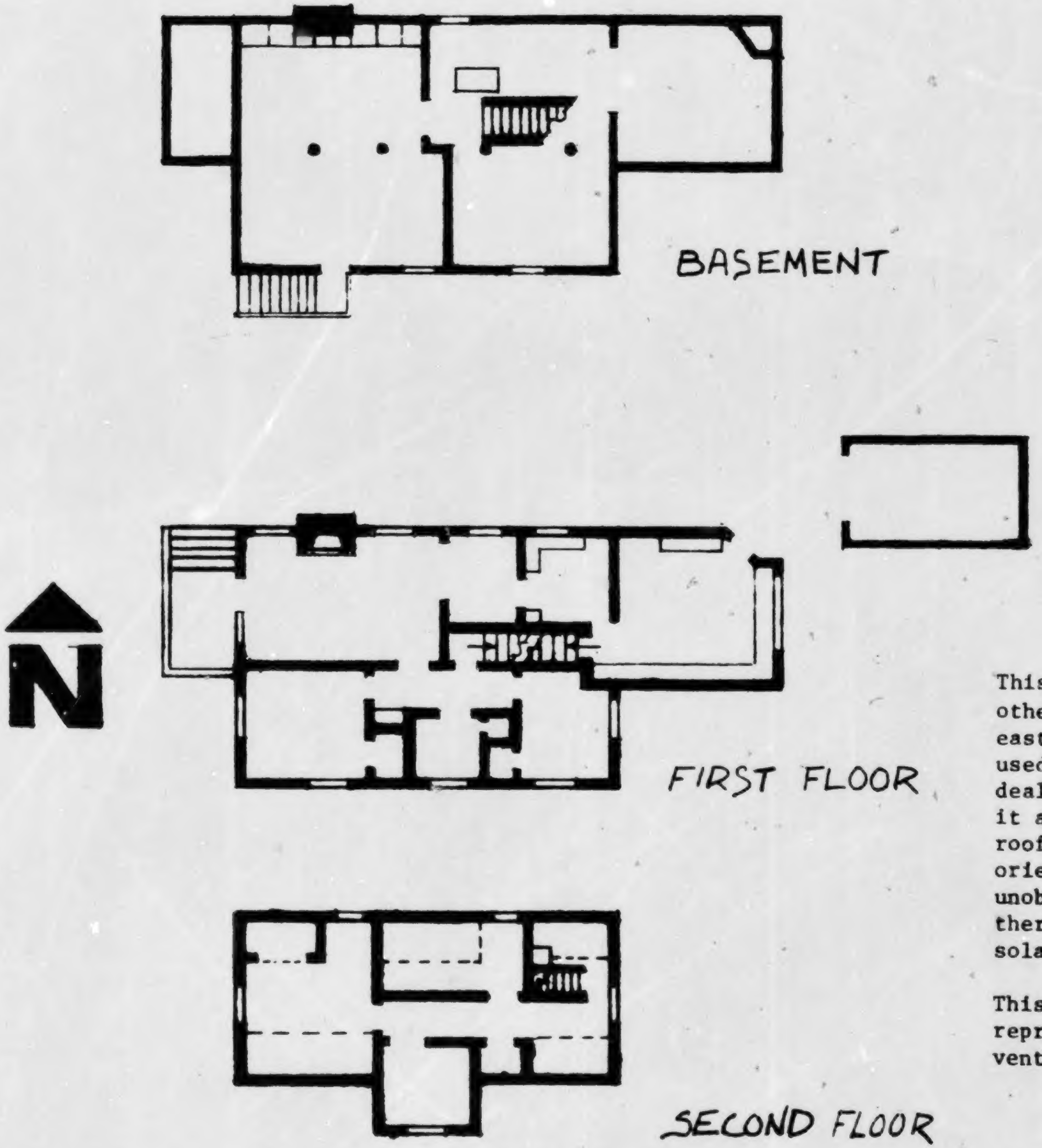
In conclusion, after working on this house for a term and surveying 100 other houses, we feel that any house can be retrofitted for solar energy. In the long run the benefits are enormous. As more people become aware of these benefits, the potential of solar energy is infinite.



A UNIVERSITY OWNED HOUSE:
1479 MOSS STREET


1479 MOSS ST.
BEAN
MOSS ST.
15TH AVE E
VILLARD ST.
N

SITE PLAN



This house is located among many other University owned houses east of campus. It is now being used as office space, but in dealing with this study we treated it as a residence. It has a gable roof with an east-west ridge orientation. It also has a nearly unobstructed southern exposure, therefore lending itself well to solar retrofitting.

This house was chosen as it represented a broad range of conventional northwest housing.

PLANS

1979 Moss -2-

SCALE 0 10'

HEAT LOSS

BTU/HR.

* BASEMENT

WALLS = 1280 □' x4 = 5120

FLOOR = 1234 □' x2 = 2468

* 1ST FLOOR

WALLS = 1250 □' x 50° x .1 = 6250

WINDOWS = 226 □' x 50° x 1.13 = 12769

* 2ND FLOOR

ROOF = 1904 x 50° x .076 = 7235

WALLS = 382 x 50° x .1 = 1910

WINDOWS = 70 x 50° x 1 = 3500

TOTAL = 39,252

TOTAL FLOOR AREA = 3474 □'

TOTAL HOUSE VOLUME = 28861 ³

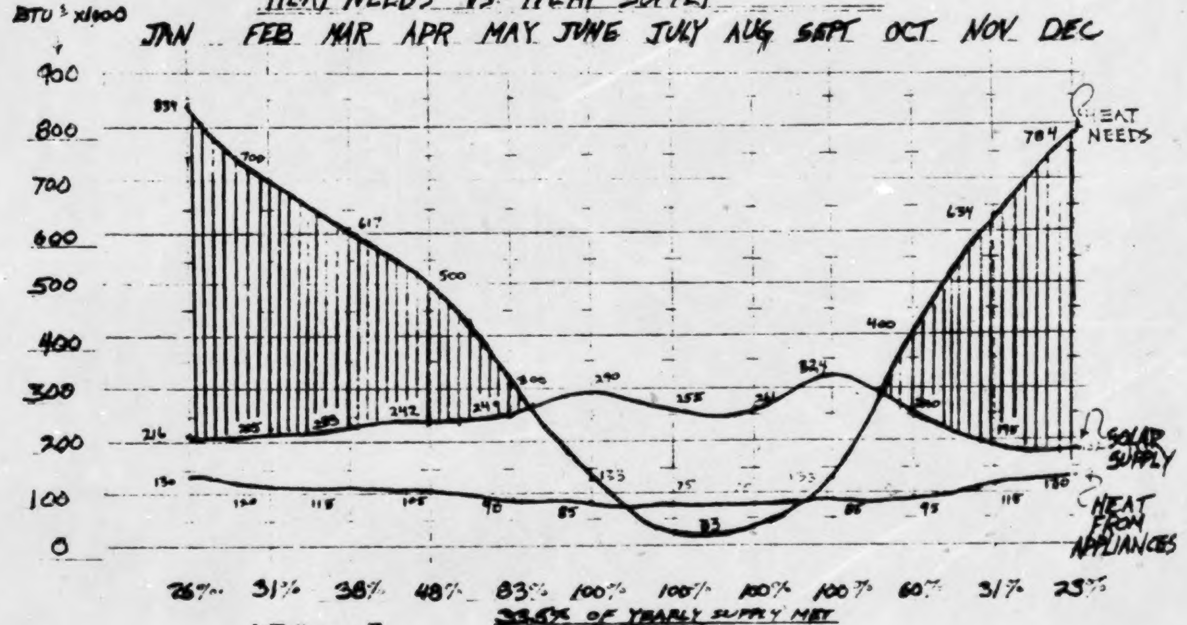
39252/3474 = 11.29 BTU/HR/□'

* 1 HR. AIR CHANGE (LUNG LOSS)

.018 x 28861 x 50/3474 = 7.47 BTU/HR/□'

TOTAL = 19.76 BTU/HR./□'

HEAT NEEDS -VS- HEAT SUPPLY



1479 Moss -3-

Preliminary:

① Heat Loss (BTU/H)

Two Methods:

I. (ΔT)(Area)(U)= g [illegible] BTU/H
g 68646 BTU/H÷ 3474 Floor Area= a 19.76 BTU/H/Ft^2

II. a(___Factor)(________Floor Area)= g _______BTU/H
'Conserving House' = 25 BTU/H/Ft^2
'Typical House' = 40 BTU/H/Ft^2

② Heat Loss (BTU/DAY)

Winter Degree Days-Av-21/Day
a(19.76 BTU/H/Ft^2)(24 Hr.) / (68 Inside Temp. - 18 Design Temp) = b 9.5 BTU/Degree Day/Ft^2

b(9.5 BTU/Degree Day/Ft^2)([illegible] Ft. Area)(21 Degree Days)= c 693,063 BTU/DAY

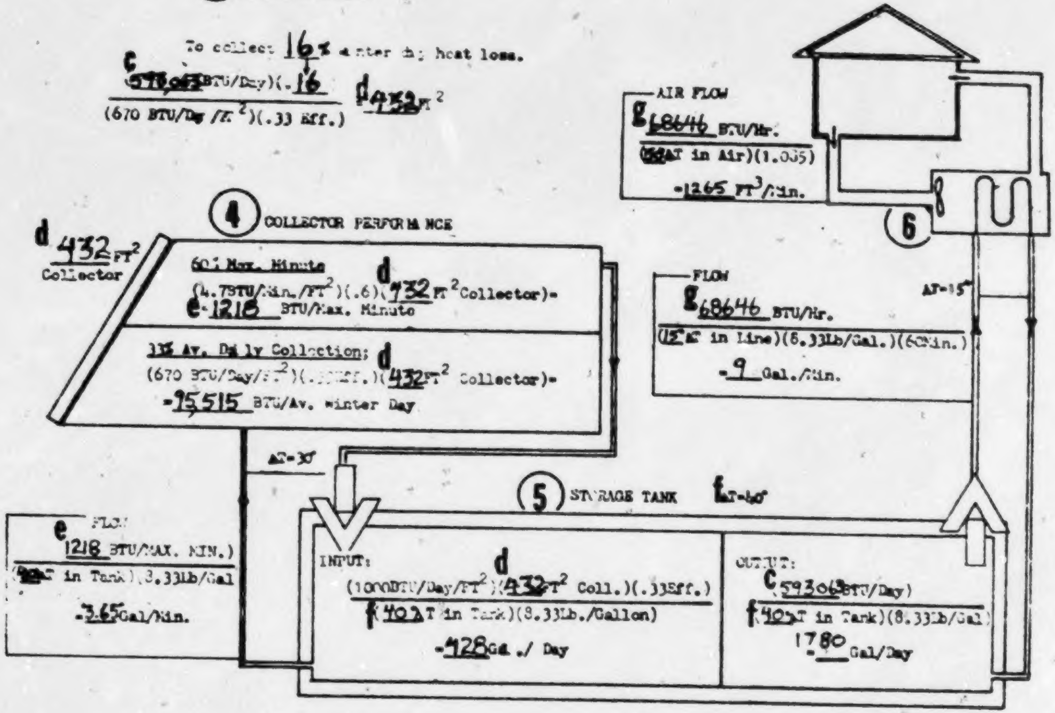
Heat gain from appliances in house = 100,000 to 130,000 BTU/DAY

Insolation Data: (per Ft^2 of collector)
Max. Minute (100%) = 4.7 BTU/Min./Ft^2
Av. Winter Day = 670 BTU/Day/Ft^2
Max. Winter Day (100%)= 1000 BTU/Day/Ft^2

③ COLLECTOR SIZING

To collect 16% winter day heat loss.

c(593,063 BTU/Day)(.16) / (670 BTU/Day/Ft^2)(.33 Eff.) = d 432 Ft^2



④ COLLECTOR PERFORMANCE

60% Max. Minute
(4.7BTU/Min./FT^2)(.6)(d 432 Ft^2 Collector)=
e =1218 BTU/Max. Minute

33% Av. Daily Collection;
(670 BTU/Day/Ft^2)(.33Eff.)(d 432 Ft^2 Collector)=
=95,515 BTU/Av. Winter Day

FLOW
e 1218 BTU/MAX. MIN.) / (40ΔT in Tank)(8.33Lb/Gal
=3.65 Gal/Min.

⑤ STORAGE TANK

INPUT:
(1000BTU/Day/FT^2)(d 432 Ft^2 Coll.)(.33Eff.) / f(40ΔT in Tank)(8.33Lb./Gallon)
=428 Gal./Day

OUTPUT:
c(593063 BTU/Day) / f(40ΔT in Tank)(8.33Lb/Gal)
=1780 Gal/Day

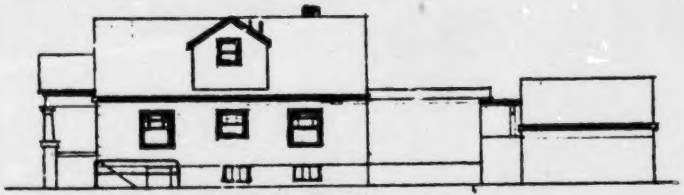
⑥

AIR FLOW
g 68646 BTU/Hr. / (50ΔT in Air)(1.085)
=1265 Ft^3/Min.

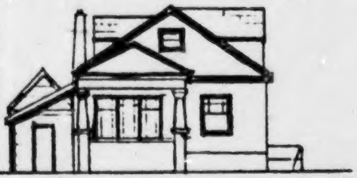
FLOW
g 68646 BTU/Hr. / (15ΔT in Line)(8.33Lb/Gal.)(60Min.)
=9 Gal./Min.

Instead of determing what size collector we would need to employ to achieve a particular percentage of the heat needs, we determined the amount of remodeling that seemed feasible and from that, the size of collector that could aesthetically and financially be incorporated. The large number of B.T.U.'s per hour loss is due to the large floor area (3474 sq.ft.) and large surface area of the house.

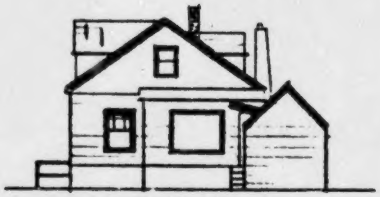
EXISTING



SOUTH FACING

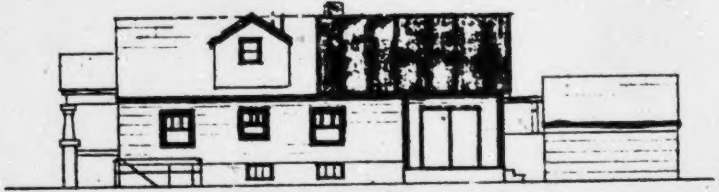


WEST FACING

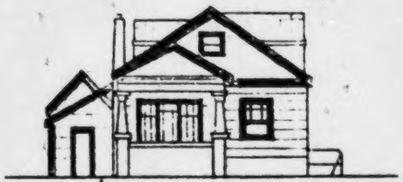


EAST FACING

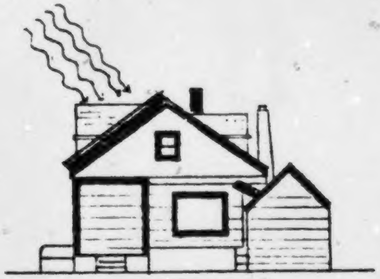
SOLAR



SOUTH FACING

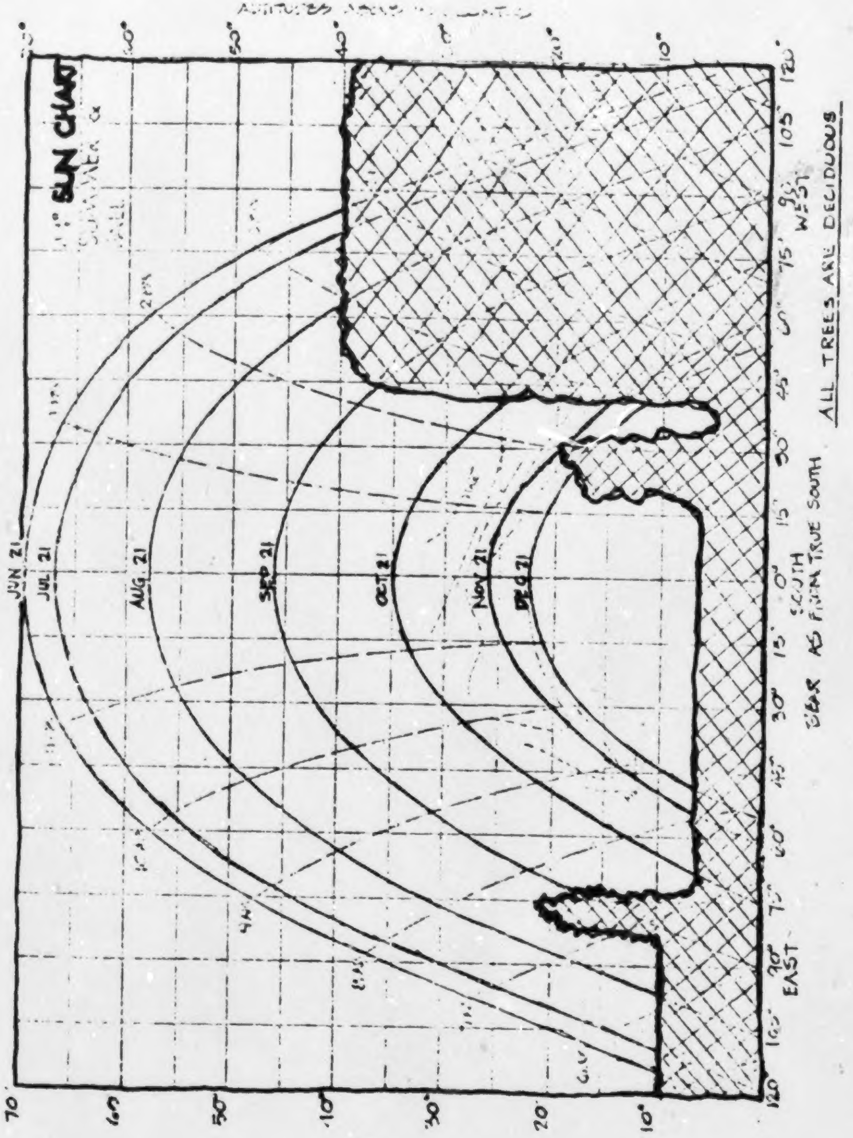


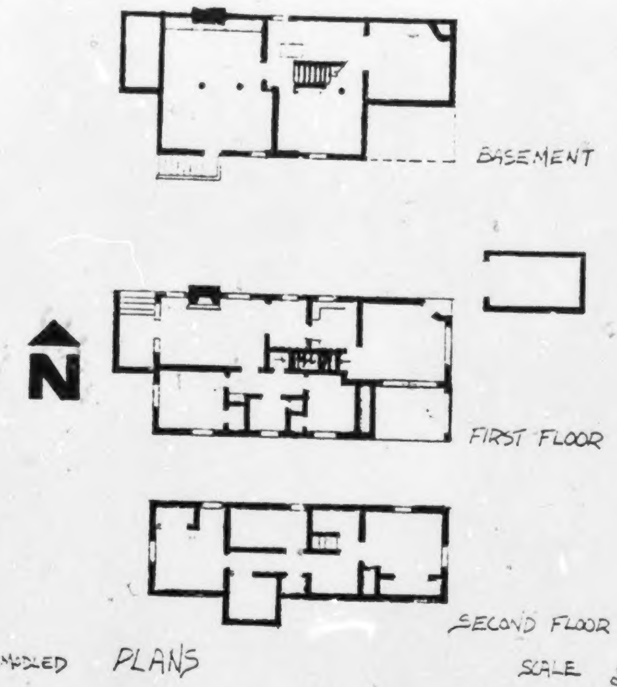
WEST FACING



EAST FACING

SUN CHART



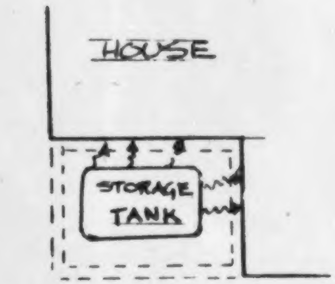

BASEMENT
N
FIRST FLOOR
SECOND FLOOR
REMODLED PLANS
SCALE
0'
10'

THE REMODEL

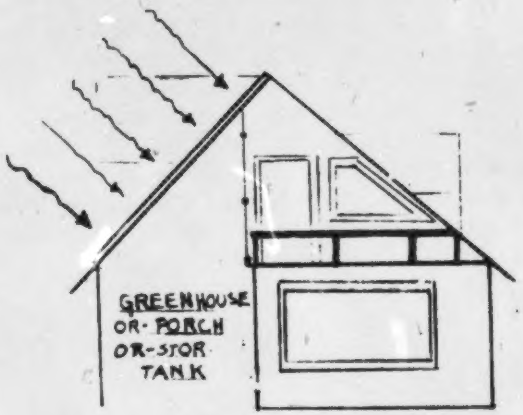
In remodeling, several priorities were involved (1) the house didn't have a good pedestrian connection to the back yard--thus porch and/or deck; (2) the house had an existing addition that was not in keeping with the original house design--thus an extended gable would simple incorporate the addition; (3) the house was in need of more space--thus another room; (4) the solar panels needed the proper orientation to the sun--thus their placement on the S.E. corner with southern exposure.

Depending upon need, anyone of the criteria we used in developing our design responses may be altered.

The back porch could become another room, a greenhouse, or even an enclosure for the solar storage tank with its inevitable heat loss radiating into the house itself.


HOUSE
STORAGE TANK

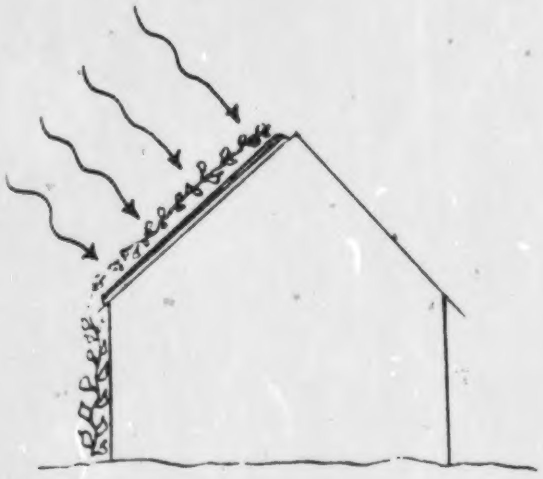
PLAN VIEW


GREENHOUSE
OR-PORCH
OR-STOR
TANK

EAST ELEVATION

The added room upstairs could remain open and the 1st floor flat roof could become a gable covered deck next to 2nd floor bedrooms with back yard privacy.

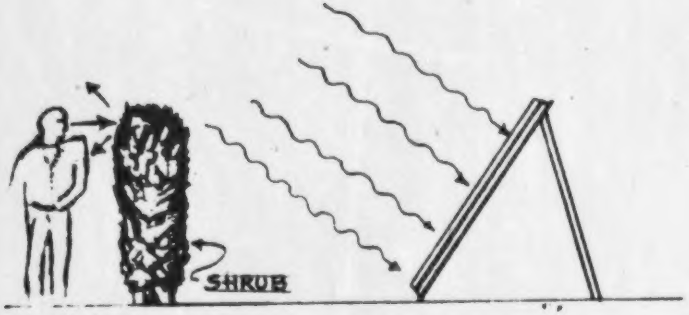
If they have adequate exposure (determined by plotting the horizon on a sun chart), the stud walls themselves could be stripped of their exterior siding and 9' x 14½" solar panels could be nailed between the studs.

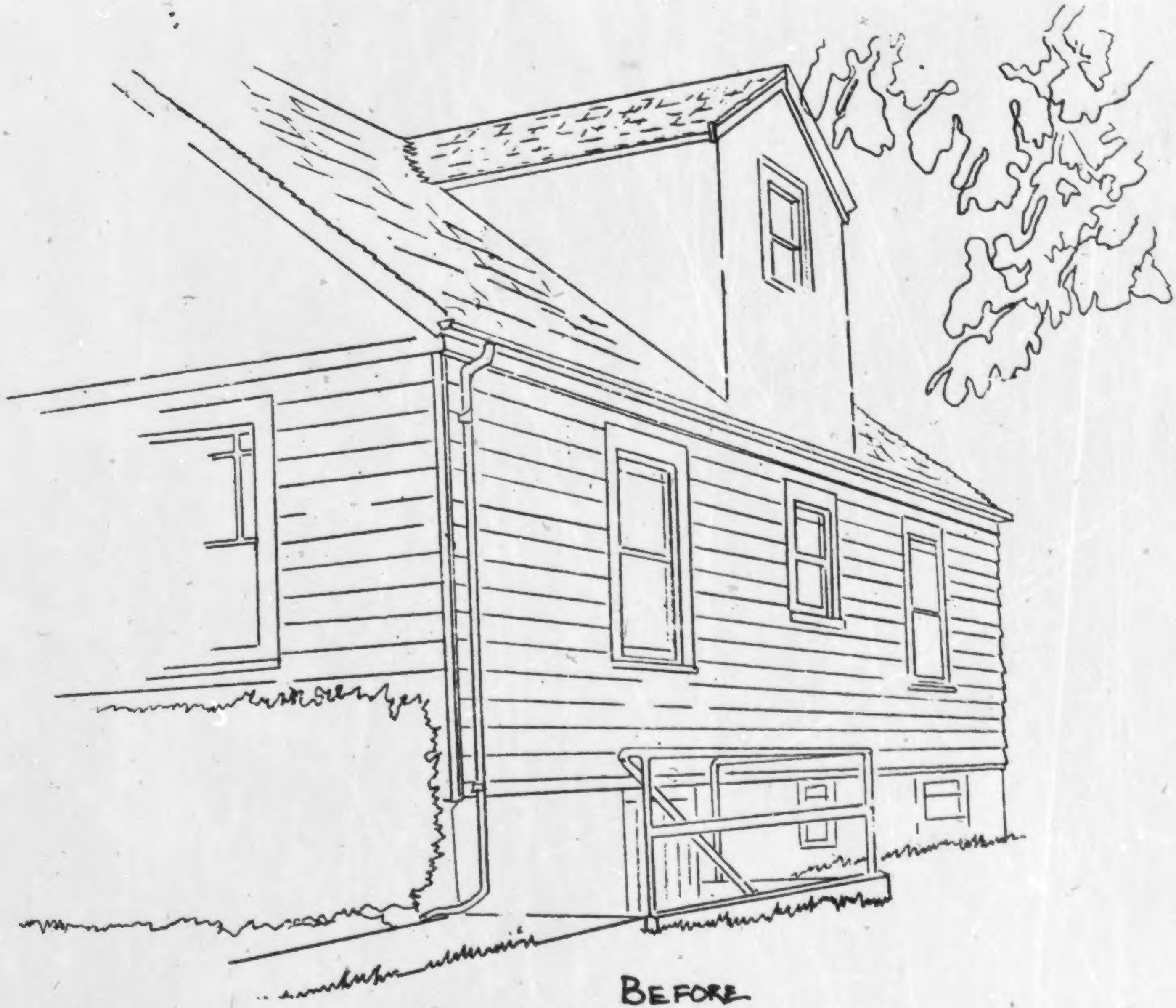


EAST ELEVATION

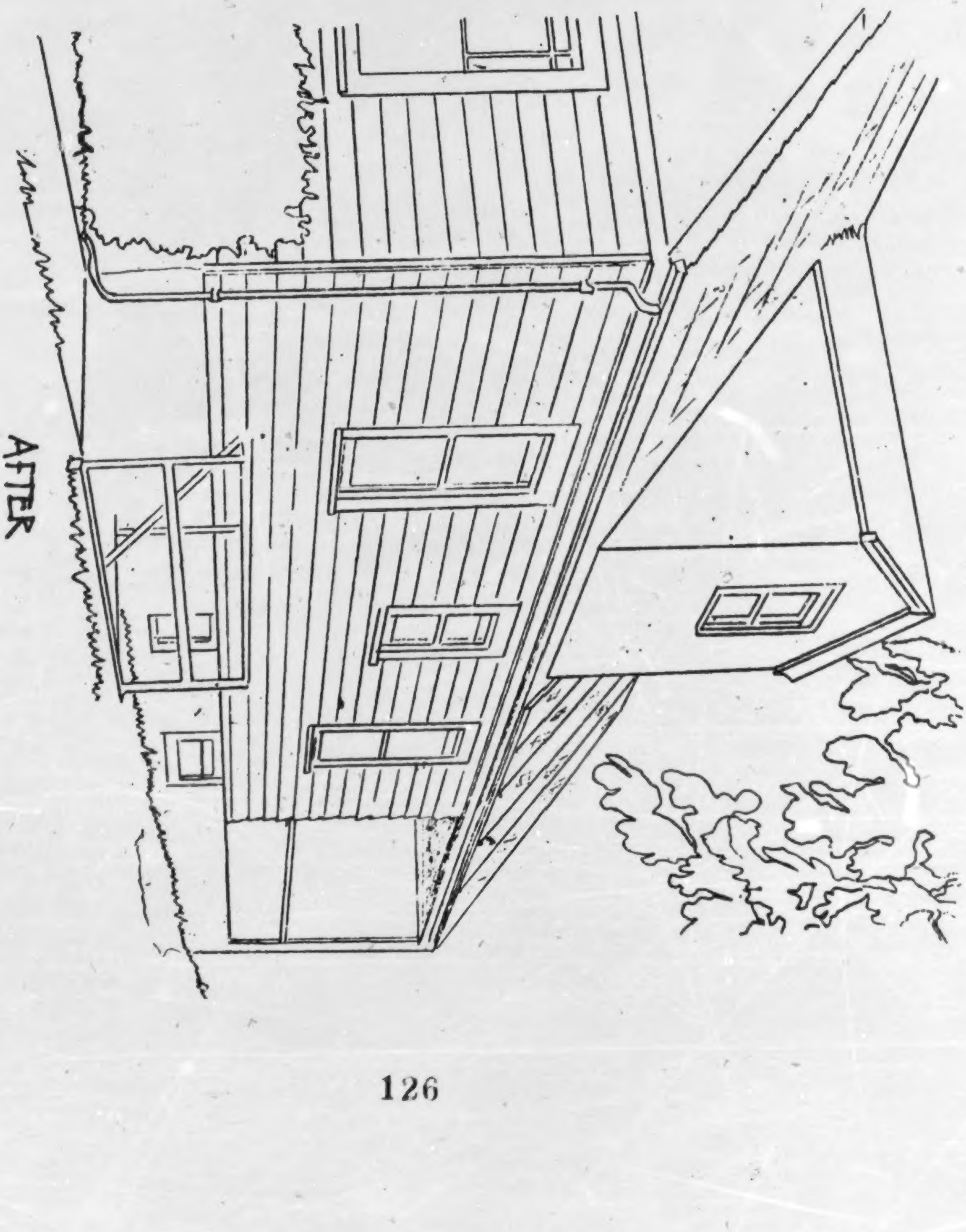
The addition allows the collector to be placed away from the tree's shade, but the trees could be trimmed to allow for more variation.

Plants could be located in various ways to act as visual shields.





BEFORE
VIEW FROM THE SOUTH



AFTER

1479 Moss -10-